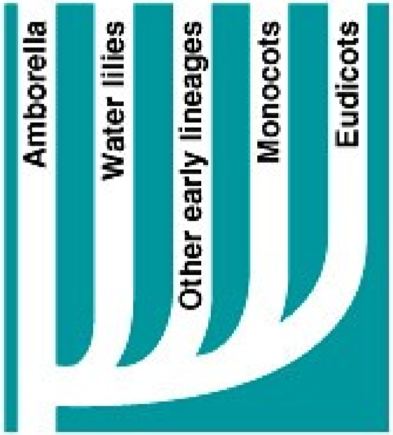
The Evolution and Diversity of Modern Angiosperms

- Defining features are flowers and fruits
- “Enclosed seeds”
- Presence of seeds within fruits
- Seed endosperm another defining feature

© Bill Ross/CORBIS

Representatives of major angiosperm clades



(a) Flowering Plants

(b) *Amborella*

(c) Water lily

(d) Star anise

(e) Orchid (monocot)

(f) California poppy (eudicot)

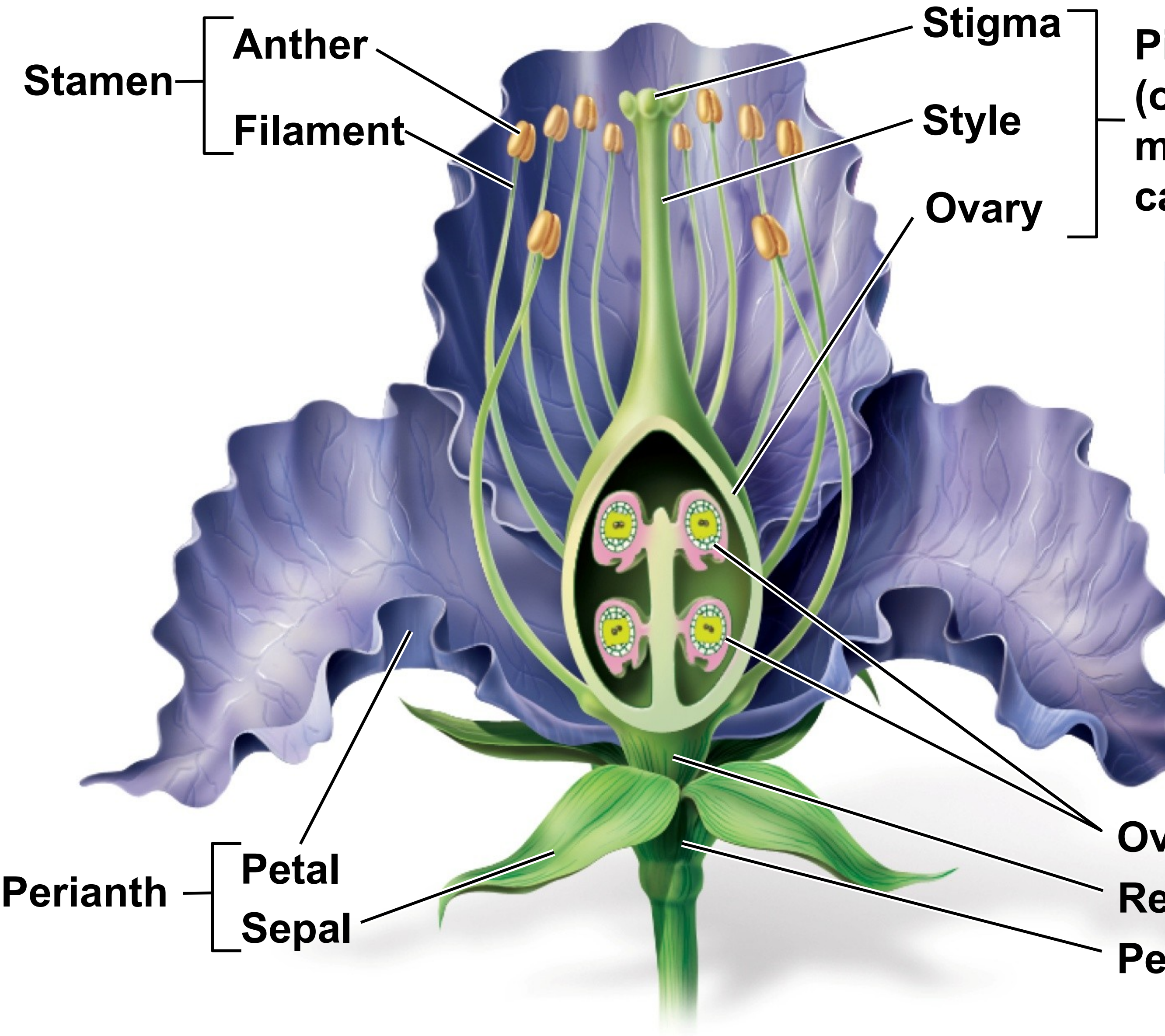
Copyright © Pearson Education, Inc., publishing as Benjamin Cummings.

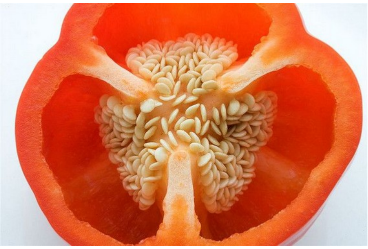
Whole Genome Duplications Influenced the Evolution of Flowering Plants

- An estimated 40–70% of all plants are **POLYPLOID**
- Two majors types of polyploidy - **review**
  - **Autoploidy** – non-disjunction results in extra chromosomes in gametes (diploid spores, gametophytes too)
  - **Alloploidy** – hybridization between 2 species with different chromosome counts followed by whole genome duplication
- Plants are also known to obtain mitochondrial genes from other plant species by horizontal gene transfer

FLOWERS

- Complex reproductive structures
- Specialized for production of pollen and seeds, and to attract pollinators (coevolution of insects)
- **Four types of organs**
  1. Sepals – green (mostly) outer layer of flower
  2. Petals – often colorful
  3. Stamens – produce pollen
  4. Carpels – produce ovules


Stamen
Anther
Filament
Stigma
Style
Ovary
Pistil (one or more fused carpels)
Petal
Sepal
Perianth
Ovules
Receptacle
Pedicel



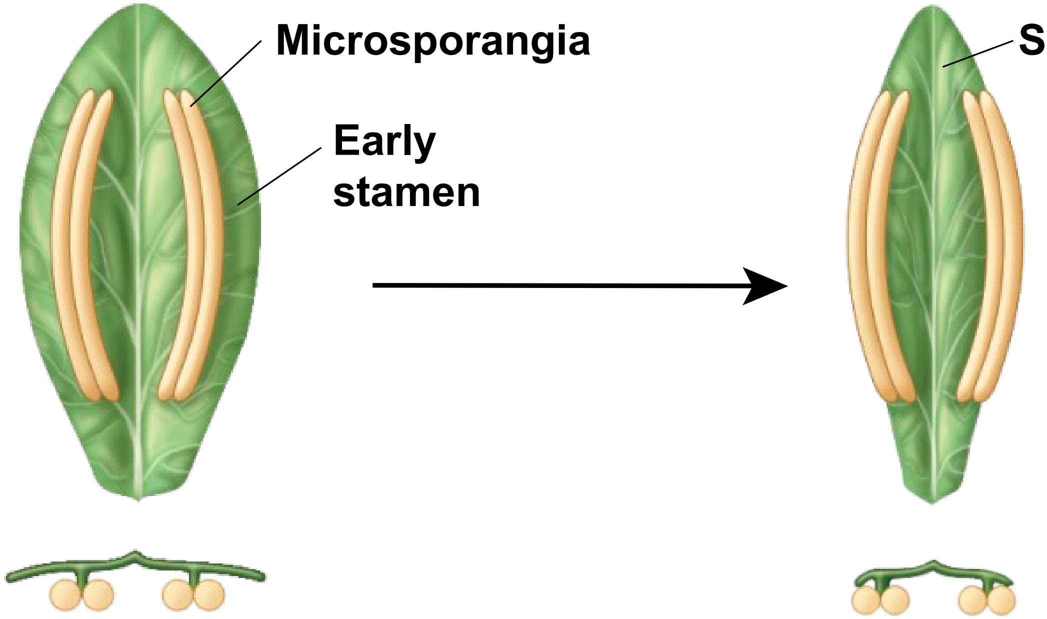
- Flower organs supported by **receptacle**
- **Pedicel** – tip of the flower stalk
- **Perianth** – petals and sepals
- **Complete flowers** – all 4 flower organs
- **Incomplete flowers** – lack one or more organs
- **Bisexual flowers** – contain both stamens and carpels
- **Unisexual flowers** – lack either stamens or carpels

- Single and compound carpels called the pistil
- **Pistil anatomy**
  - ❑ **Stigma** – receives and recognizes pollen
    - Only appropriate pollen will be allowed to germinate
  - ❑ **Style** – long middle portion
  - ❑ **Ovary** – encloses and protects ovules
    - Pollen tube delivers sperm to ovule
    - Ovaries develop into fruits

Early flowers

- First appeared 140 mya (mammals at 210mya)
- Flowers were a **critical innovation** that led to extensive angiosperm diversification
- **Stamen** development
  - ❑Early flowers had broad leaf-shaped stamens
  - ❑Narrowed to form filaments and anthers (clusters of microsporangia with pollen)
- **Carpels** also developed from leaf-like structures
  - ❑Folded to protect ovules

1. **Early stamens were leaflike, with microsporangia on the surface.**
2. **Stamens later became narrower.**



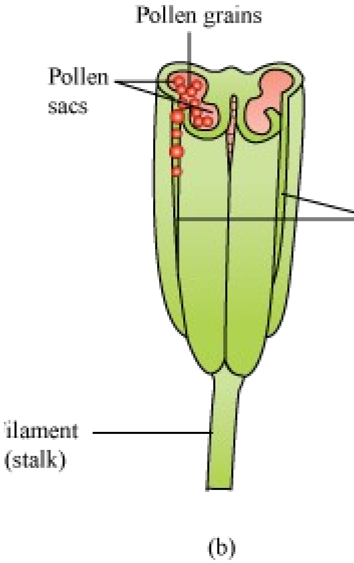
Front view

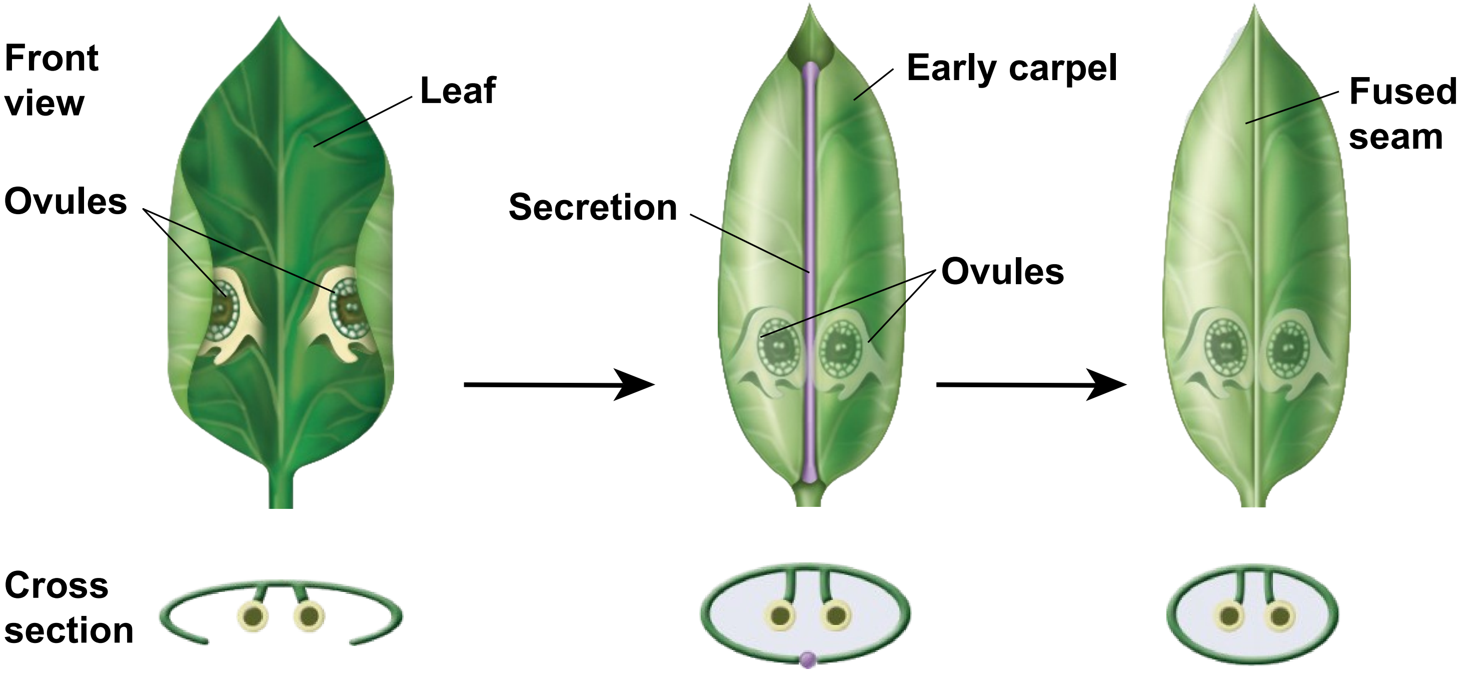
Microsporangia

Early stamen

Stamen

Cross section

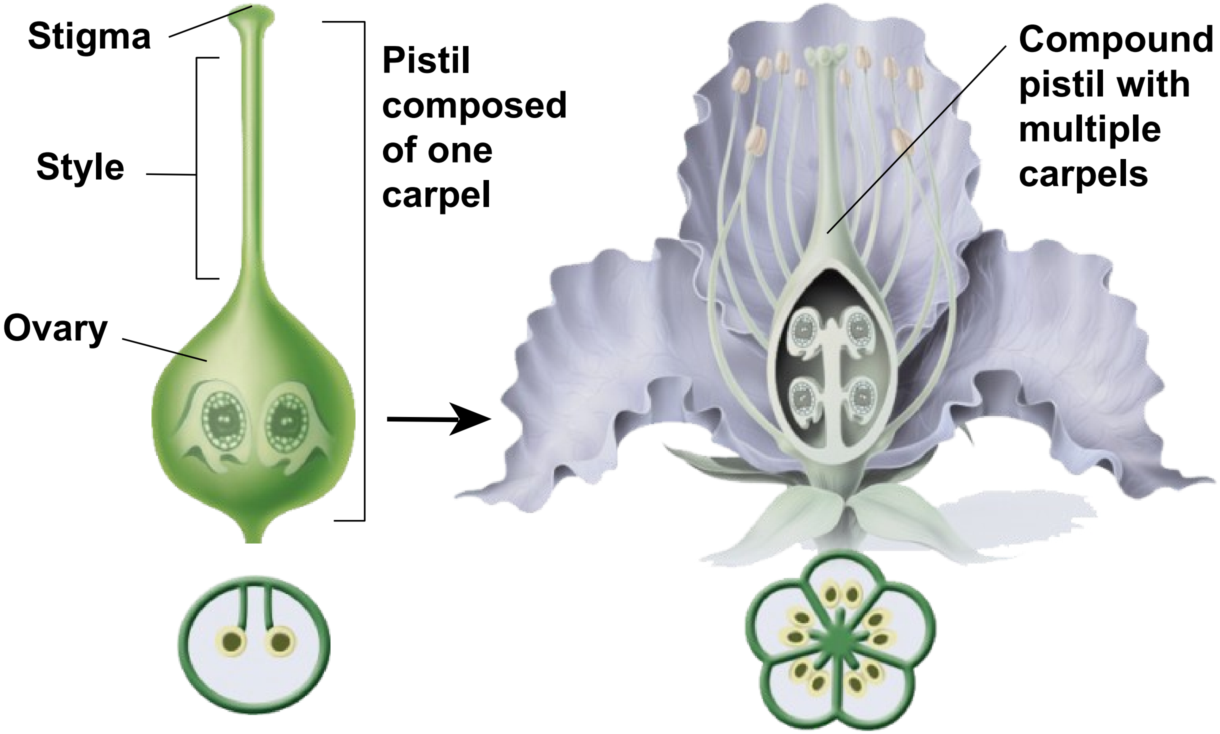




1 Carpels evolved from leaflike structures whose edges folded over ovules, protecting them.

2 Early carpels folded over ovules, with the seam closed by sticky secretions.

3 Later carpels were completely closed into a tube, by fusion of tissue.


Stigma
Style
Ovary
Pistil composed of one carpel
Compound pistil with multiple carpels

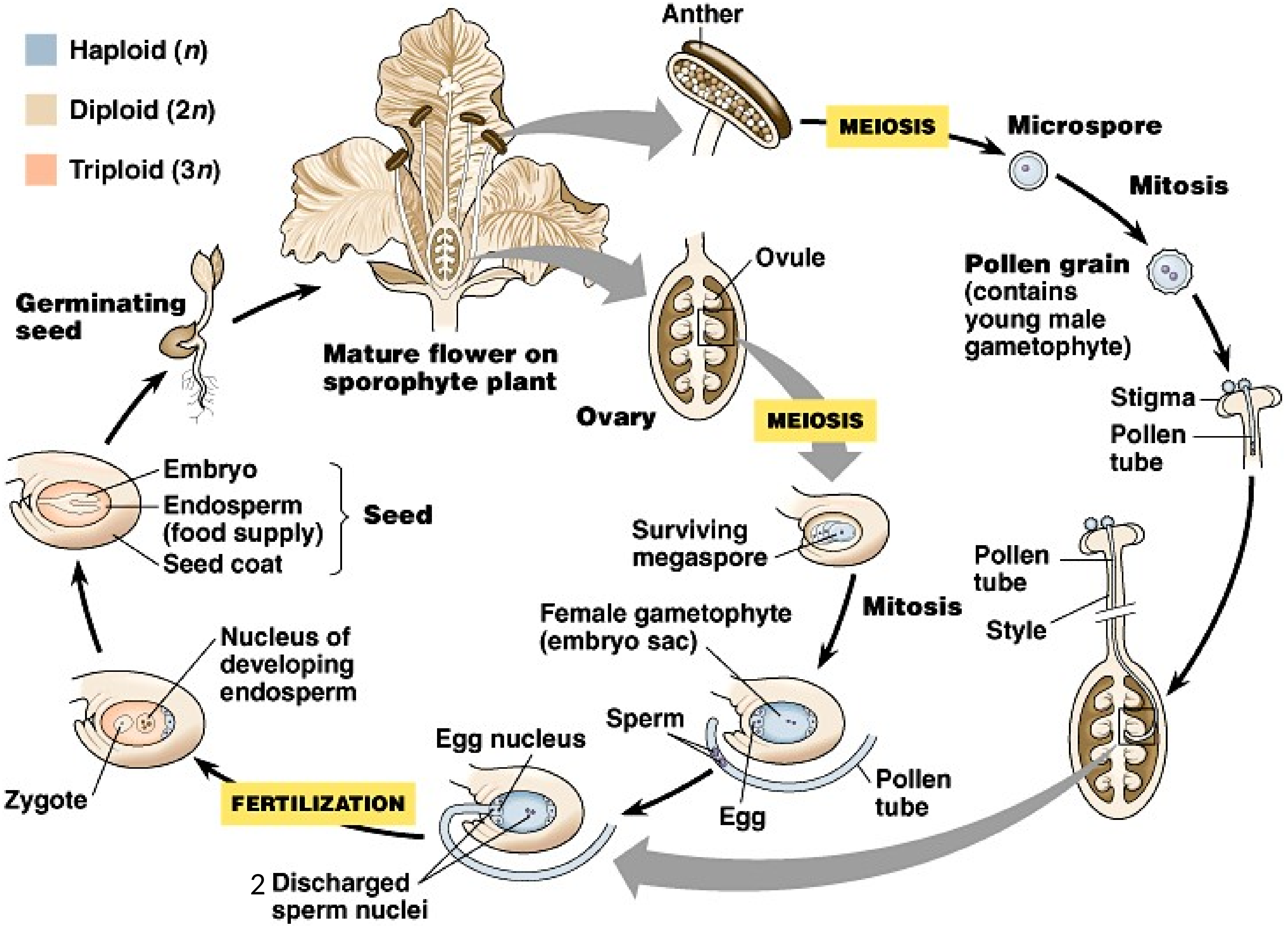
4 Carpels developed specialized regions (stigma, style, and ovary) to form a pistil.

5 In many modern flowers, several to many carpels fuse to form a compound pistil.

DOUBLE FERTILIZATION

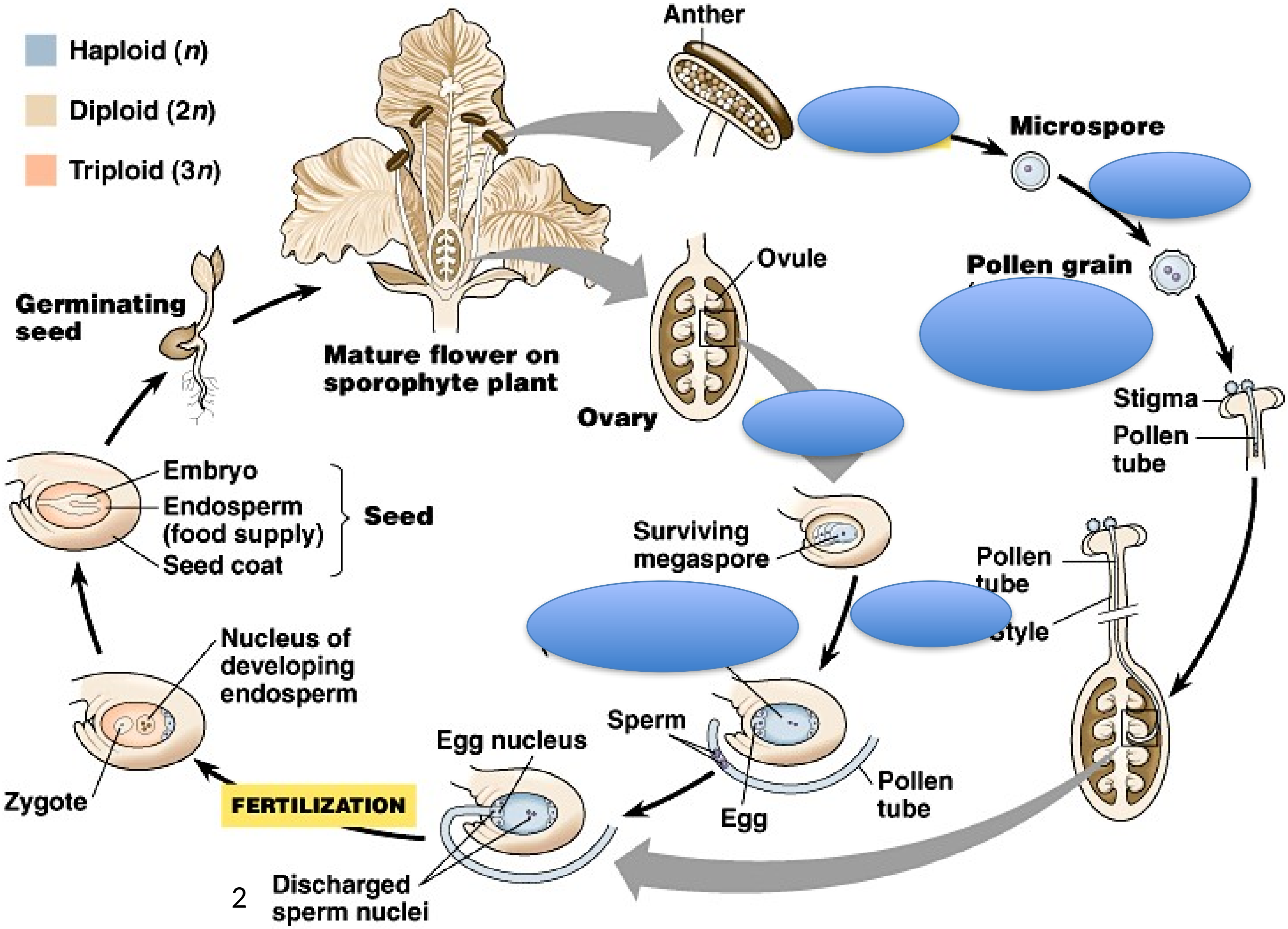
- Fertilization occurs **AFTER** pollination
- Male gametophyte extends pollen tube carrying 2 sperm nuclei toward the egg
  - **One sperm nucleus** fertilizes egg to become an embryo
  - **The other sperm** fuses with different female gametophyte tissue to form **ENDOSPERM**
  - Ovule's integument develops into a protective, hard and tough seed coat
- Seeds allow embryos access to food supplied by the older sporophyte generation

The life cycle of an angiosperm

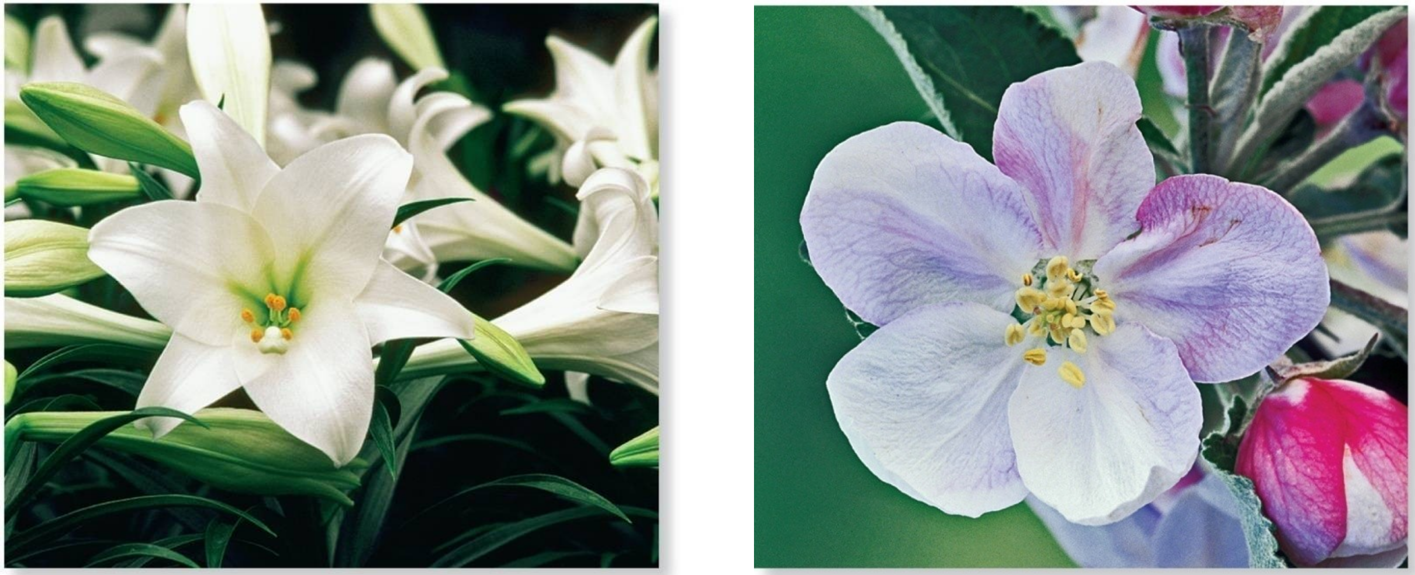


Copyright © Pearson Education, Inc., publishing as Benjamin Cummings.

The life cycle of an angiosperm



Copyright © Pearson Education, Inc., publishing as Benjamin Cummings.


(a) A monocot with six tepals **(b) A eudicot with five petals**

a: © Medioimages/PunchStock RF; b: © Ed Reschke/Getty Images

- **Monocots** and **eudicots** are named for differences in the number of embryonic leaves called **COTYLEDONS**
- Monocots differ from eudicots in several additional ways

Table 35.1 Distinguishing Features of Eudicots And Monocots, Two Major Groups Of Flowering Plants

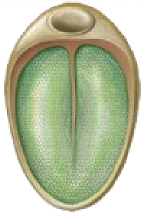
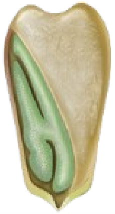
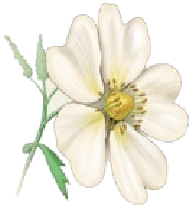
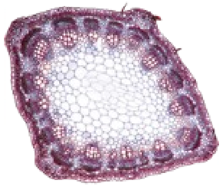
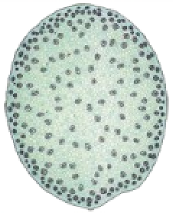
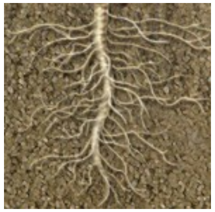
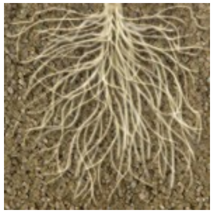
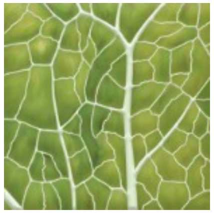
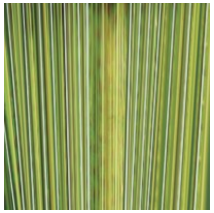
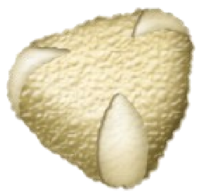
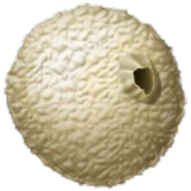
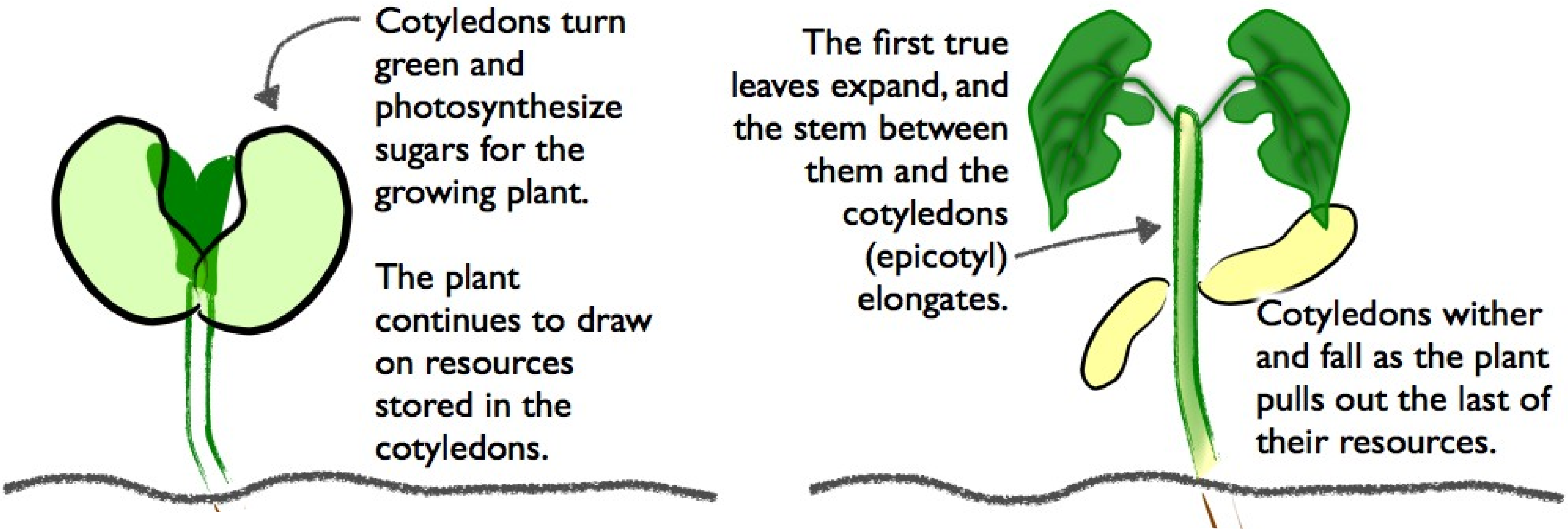
Feature	Eudicots	Monocots
Number of seed leaves (cotyledons)	Two 	One 
Number of flower parts	Usually four, five, or multiples of these 	Usually three or multiple of three
Stem vascular bundles	Arranged in a ring 	Scattered 

Table 35.1 Distinguishing Features of Eudicots And Monocots, Two Major Groups Of Flowering Plants

Feature	Eudicots	Monocots
Root system	**Branched taproot** 	**Fibrous; adventitious** 
Leaf venation	**Netted or branched** 	**Often parallel** 
Pollen	**Three pores or slit** 	**One pore or slit** 



Cotyledons turn green and photosynthesize sugars for the growing plant.

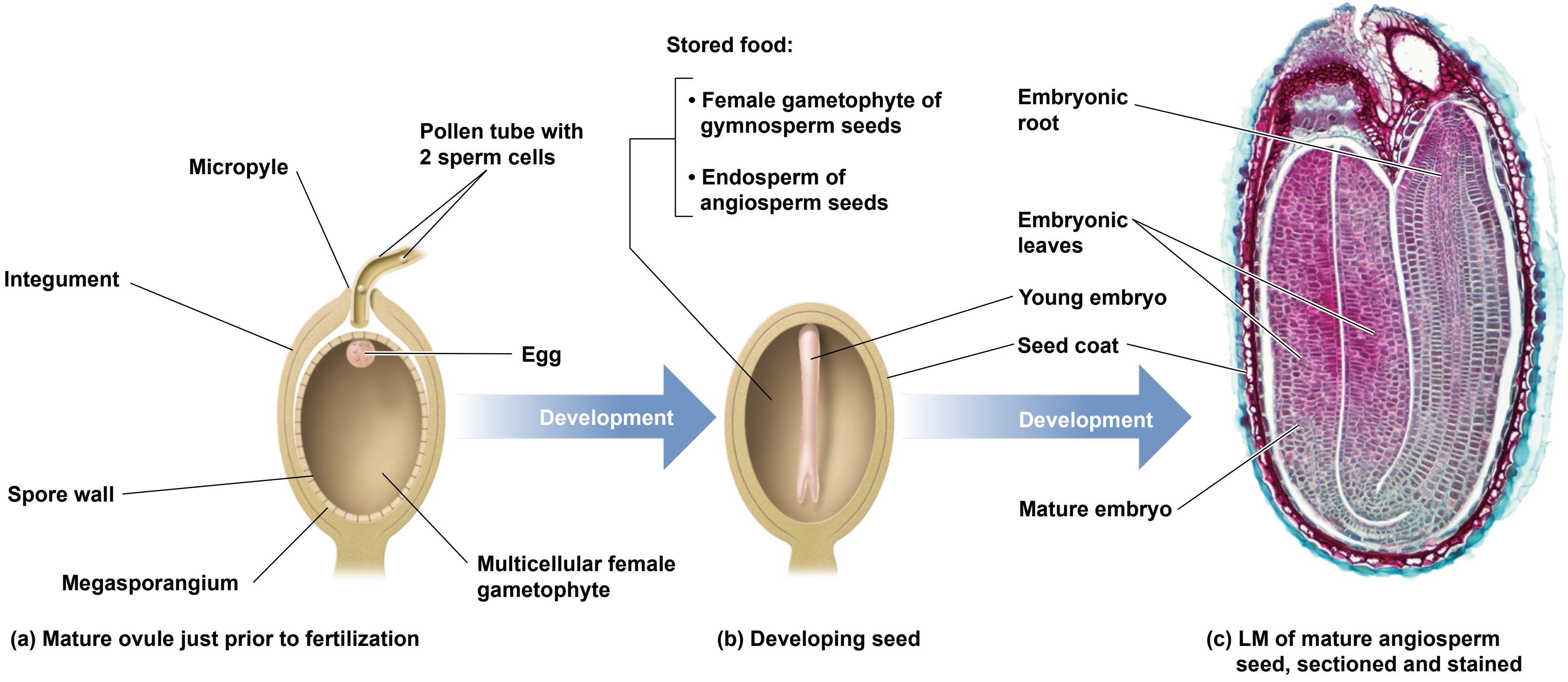
The plant continues to draw on resources stored in the cotyledons.

The first true leaves expand, and the stem between them and the cotyledons (epicotyl) elongates.

Cotyledons wither and fall as the plant pulls out the last of their resources.

- Energy for developing seed (zygote to mature embryo) comes from **endosperm**.
  - In many eudicots, cotyledons absorb and store endosperm to support embryo growth and for future seedling growth
  - In other plants, cotyledons absorb and then transfer carbohydrates directly to embryo and later seedling
- **Radicle** – embryonic root, first organ to emerge from germinating seed
  - Provides water and minerals for growth

General seed development



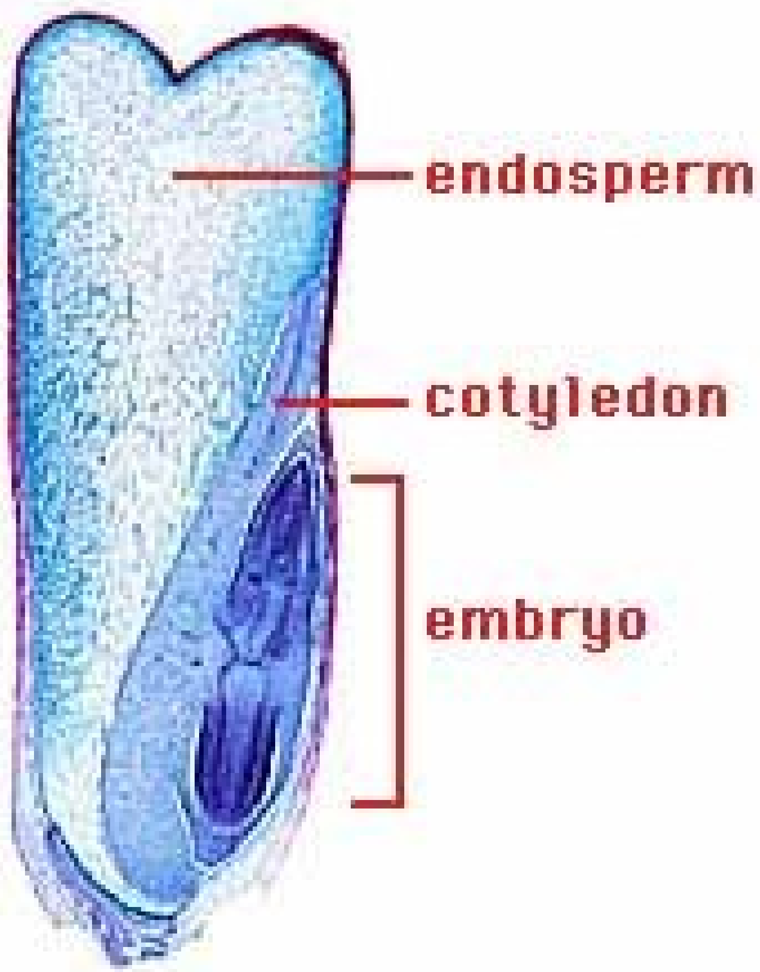
(a) Mature ovule just prior to fertilization

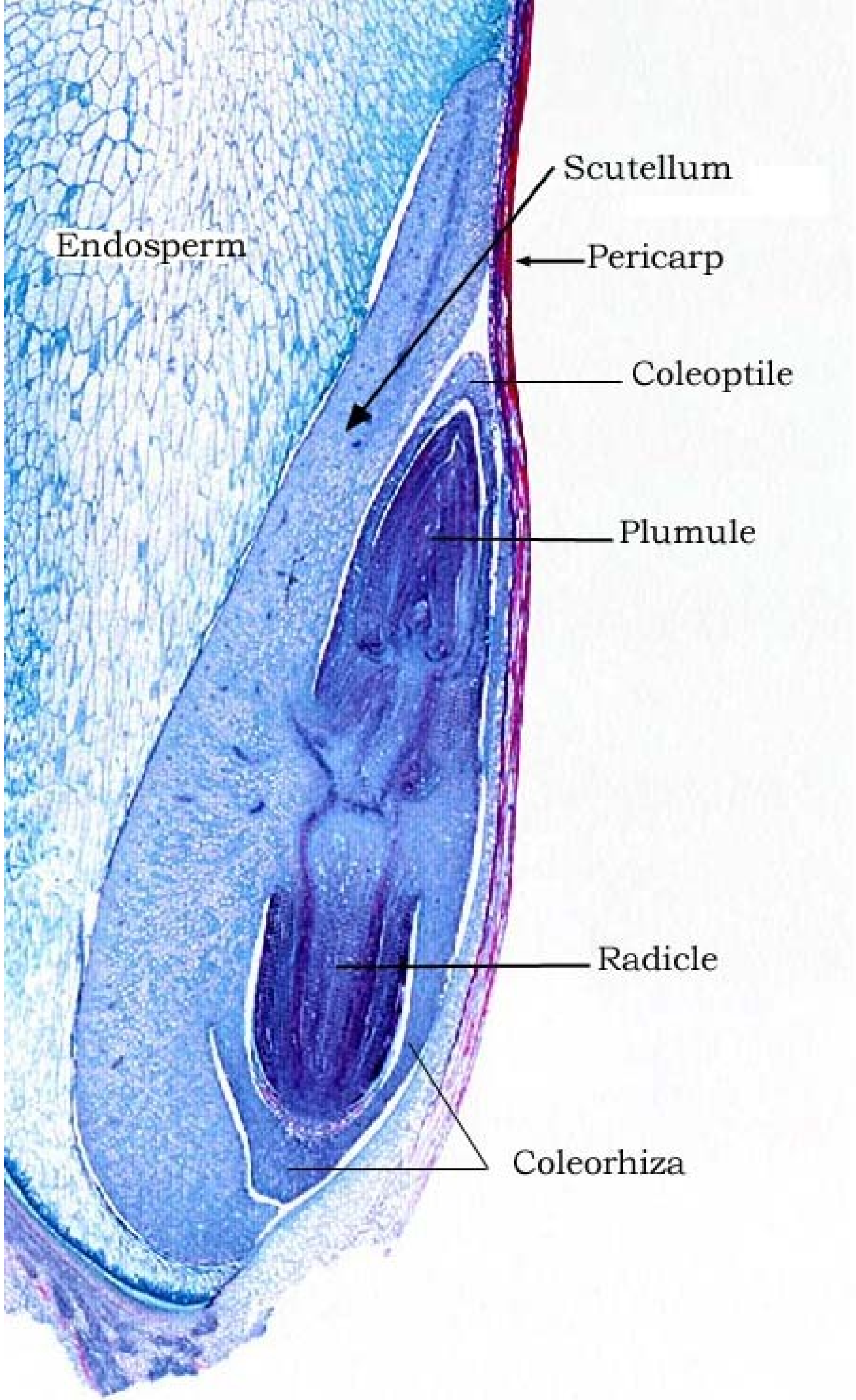
(b) Developing seed

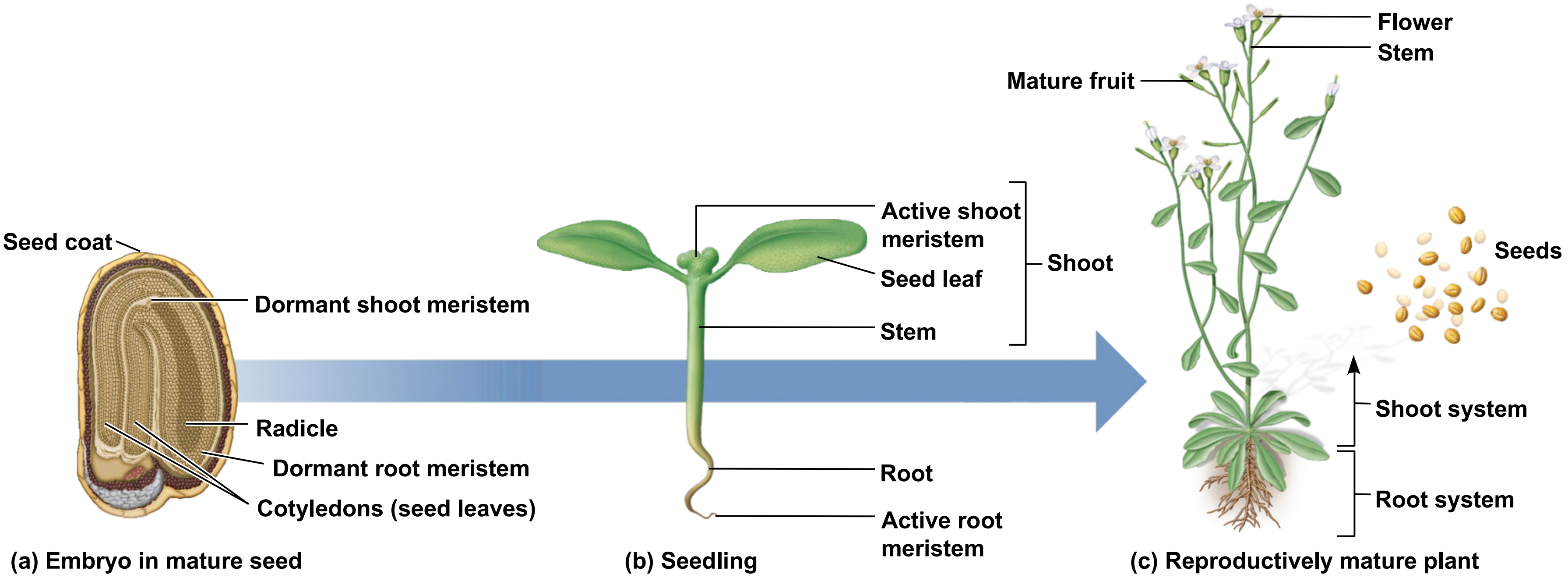
(c) LM of mature angiosperm seed, sectioned and stained

© Lee W. Wilcox

Monocot

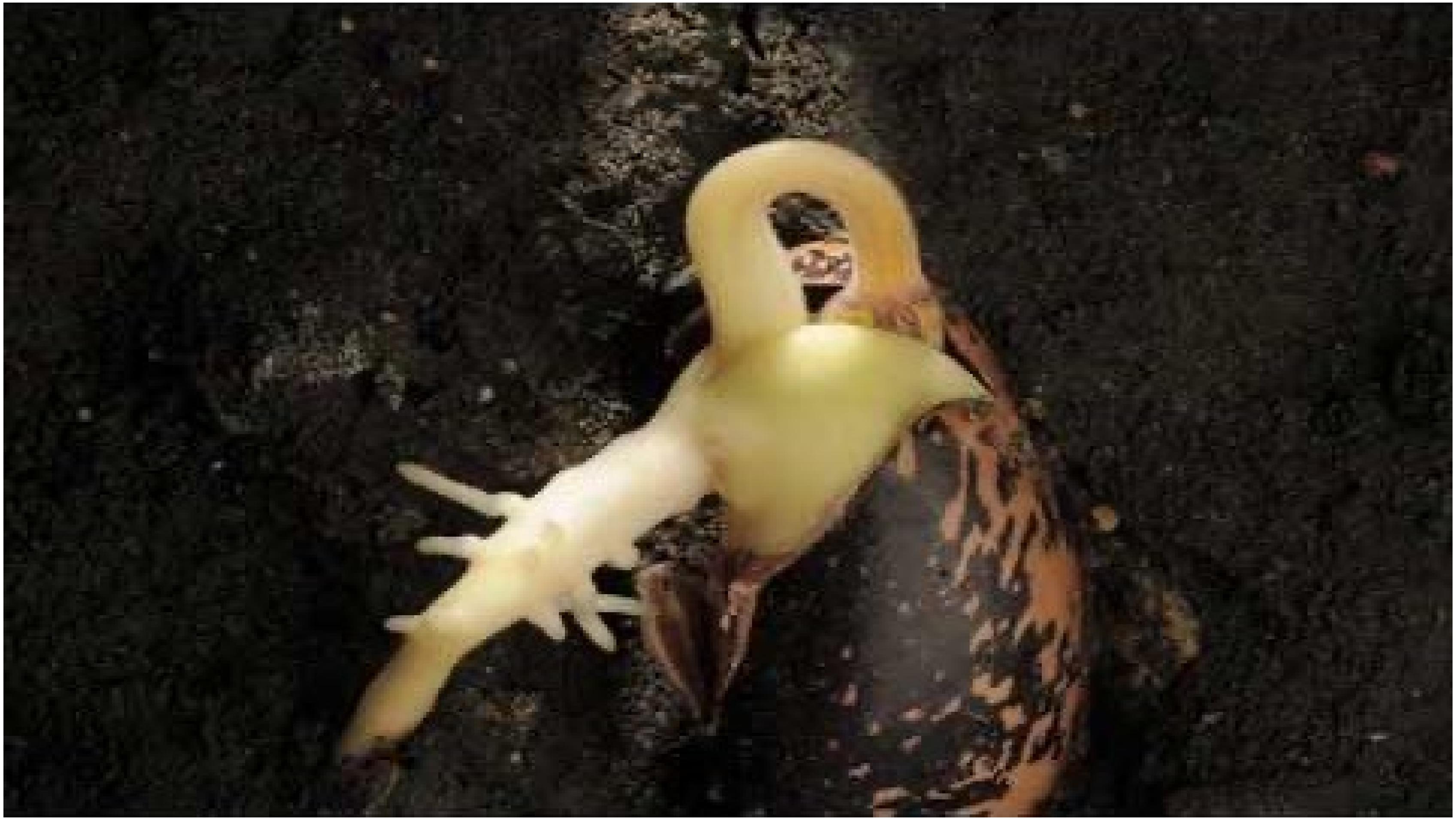

endosperm
cotyledon
embryo


Scutellum
Endosperm
Pericarp
Coleoptile
Plumule
Radicle
Coleorhiza



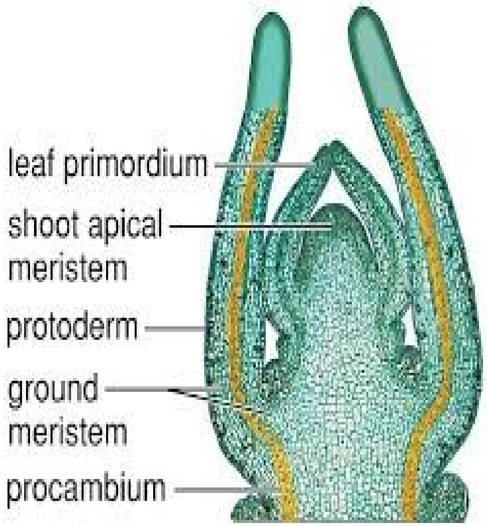
- **Shoot** – stem and leaves
- **Shoot system** – Multiple stems and leaves of plant
- **Root system** – All the plant’s roots

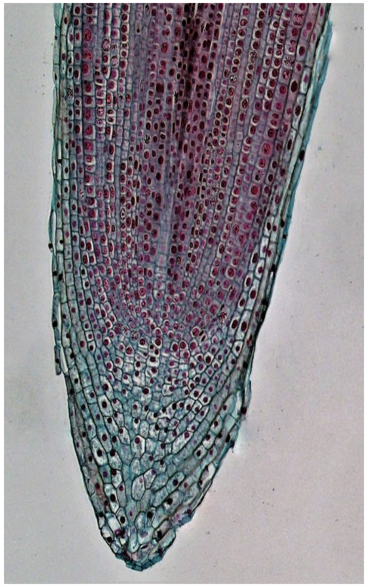
Bean germination

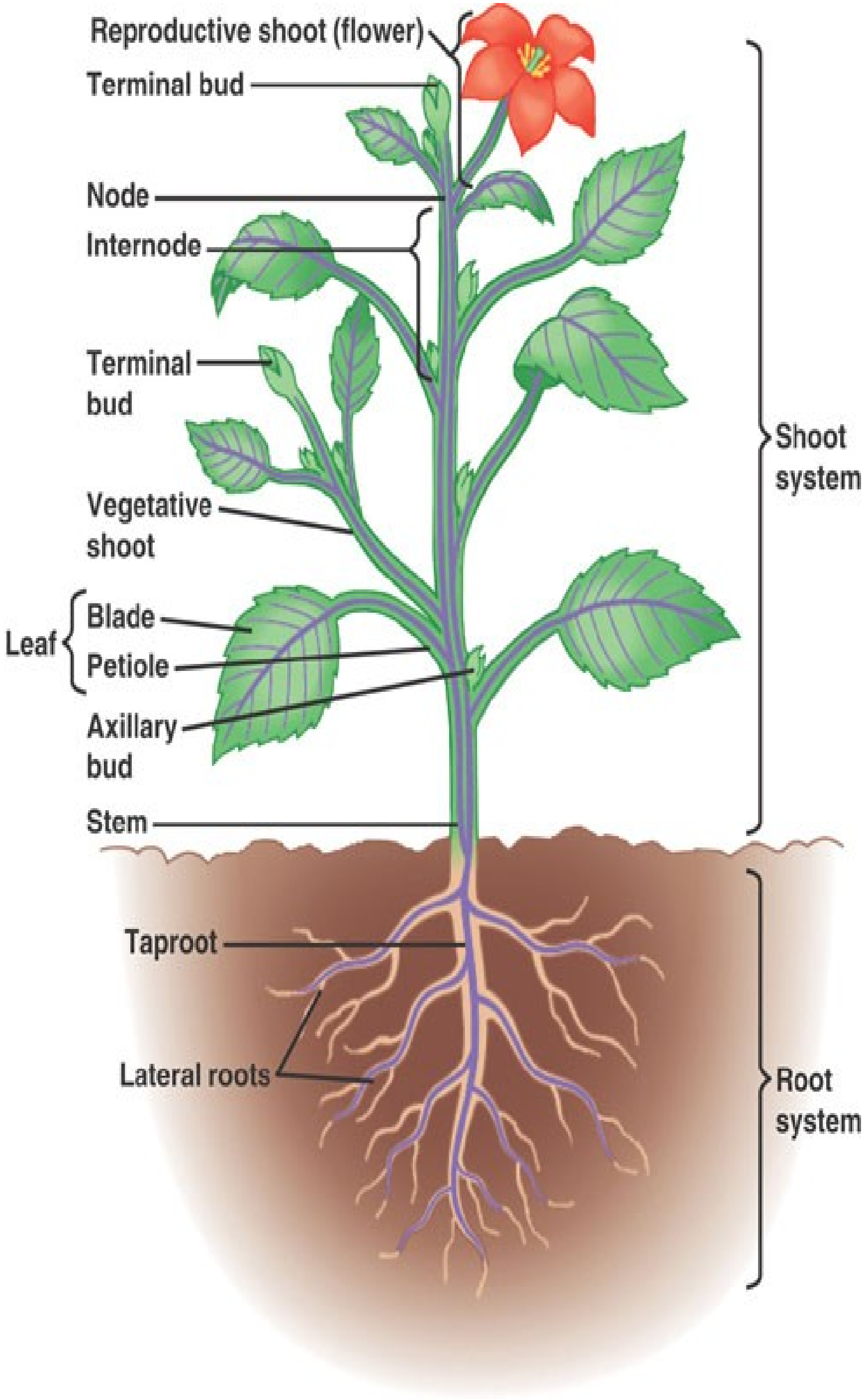


Monocot vs dicot germination

- Seedlings and mature plants produce new tissue from **meristems**
  - Meristem is a region of **undifferentiated cells** that produce new tissues by mitotic cell division
  - Dormant meristem occurs at **shoot and root tips** of seed embryos
  - Mature plants have **shoot and root apical meristems (one of the derived characters of seed plants)**

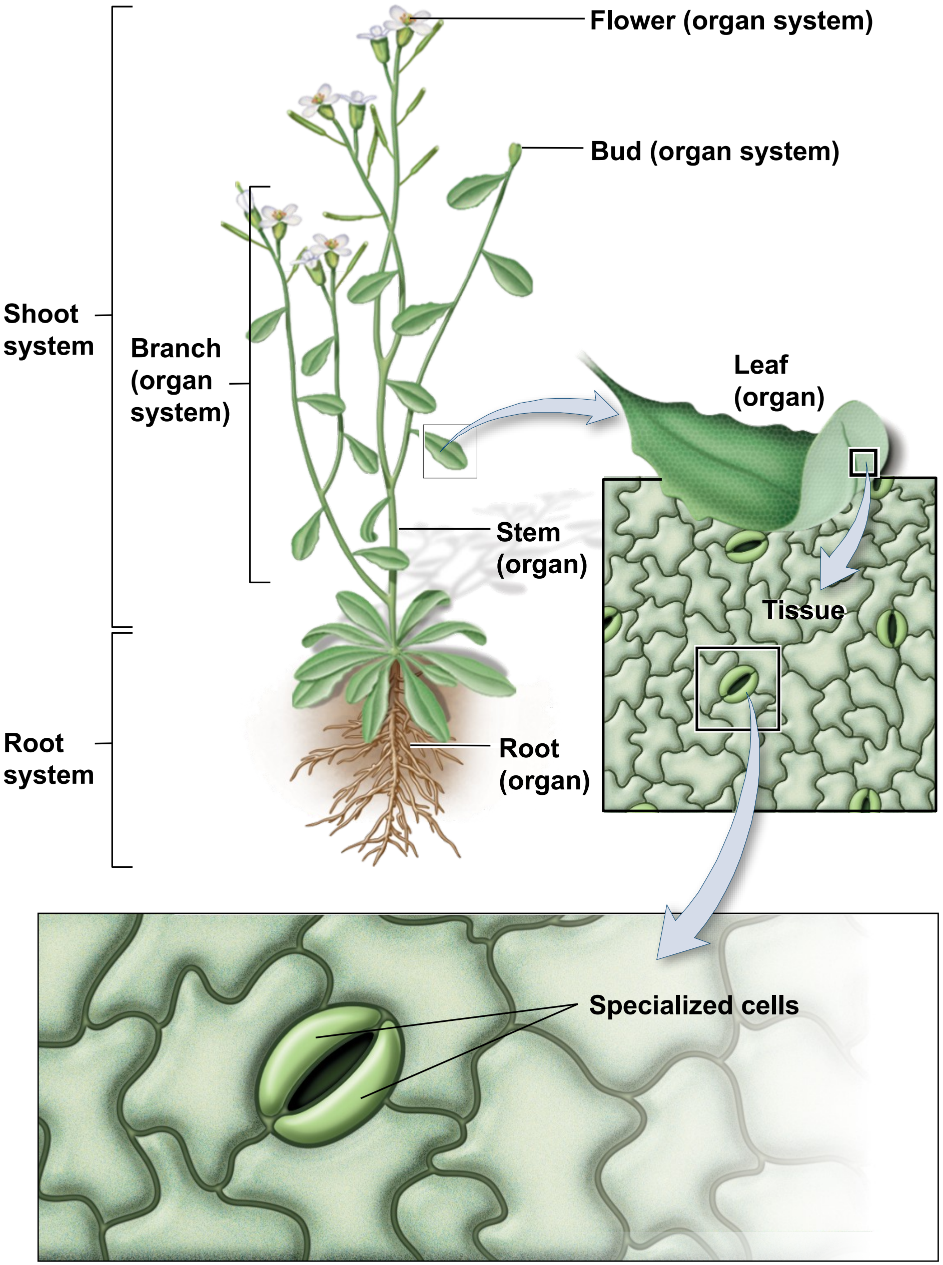






- Carbon acquisition
- Water Loss

- Water uptake
- Nutrient uptake


Flower (organ system)
Bud (organ system)
Shoot system
Branch (organ system)
Leaf (organ)
Stem (organ)
Tissue
Root system
Root (organ)
Specialized cells

How Plants Grow and Develop

- **Vegetative Growth –** Process that increases the size of the shoot and root systems
- Plant shoots produce **buds**
  - Each has a miniature shoot with a dormant shoot apical meristem
  - Under favorable conditions, buds produce new stems and leaves
  - Buds are an organ system, because they contain more than one organ
- **Indeterminate growth** – continuously produce new stem tissue and leaves as long as conditions are favorable

Reproductive development

- Mature plants produce reproductive structures – **flowers**, **seeds** and **fruits**
- Flowers and floral buds are **reproductive shoots** that develop when shoot apical meristems produce flower parts instead of new stem tissues and leaves (Determinate growth)

- Flowers are produced by **determinate growth** – growth of limited duration
- Flower tissues produce tiny **male (pollen) and female (ovary) gametophytes**
- Following double fertilization the seed starts to develop surrounded by a maturing ovary that forms the fruit.
- Fruits are commonly specialized to enclose seeds and function in **seed dispersal**

The Shoot System: Stem and Leaf Adaptations

- Shoots are formed of **modules (phytomeres)**:

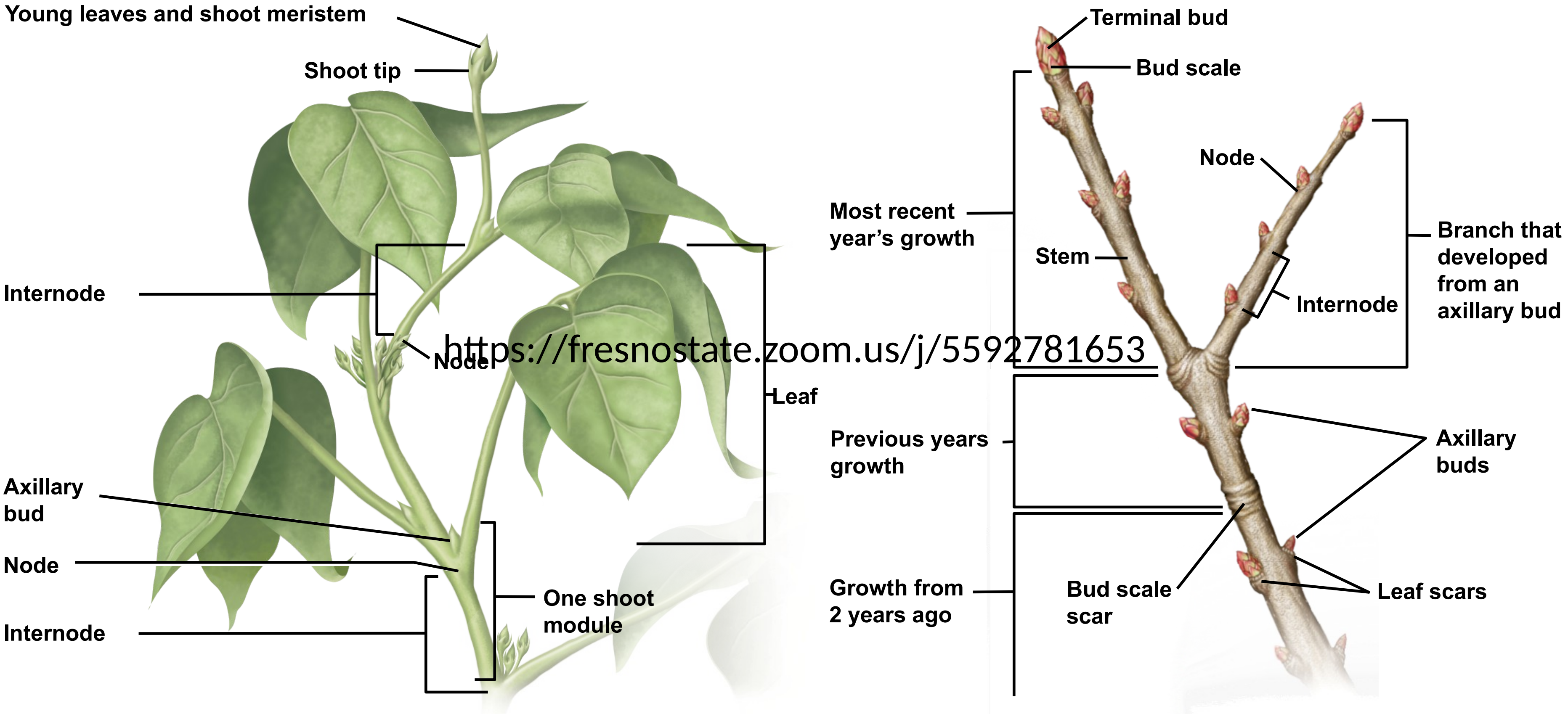
1. Stem node – leaves and axillary buds emerge

Axillary meristem – generate axillary buds

- Can produce flowers or branches (lateral shoots)

2. Internode – between adjacent nodes

3. Leaf

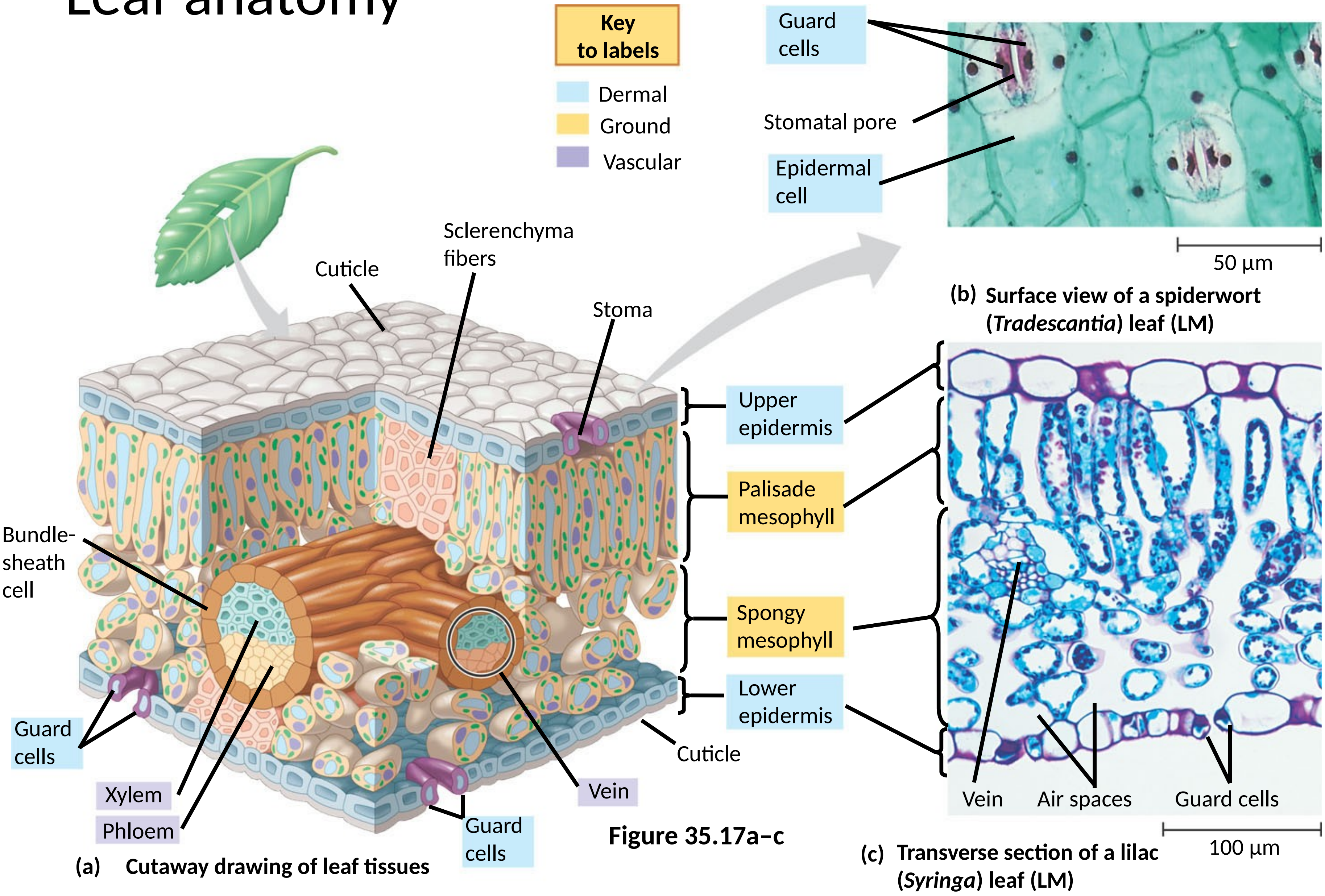


https://fresnostate.zoom.us/j/5592781653

(a) Modular structure of herbaceous shoot

(b) Modular structure of woody shoot in winter

- Leaf anatomy

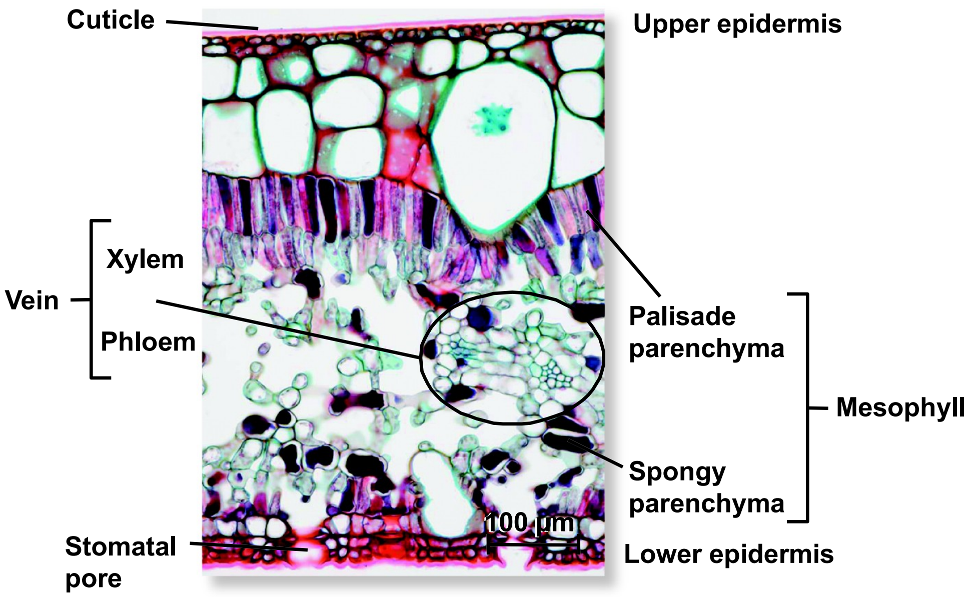


(a) **Cutaway drawing of leaf tissues**

(b) **Surface view of a spiderwort (*Tradescantia*) leaf (LM)**

(c) **Transverse section of a lilac (*Syringa*) leaf (LM)**

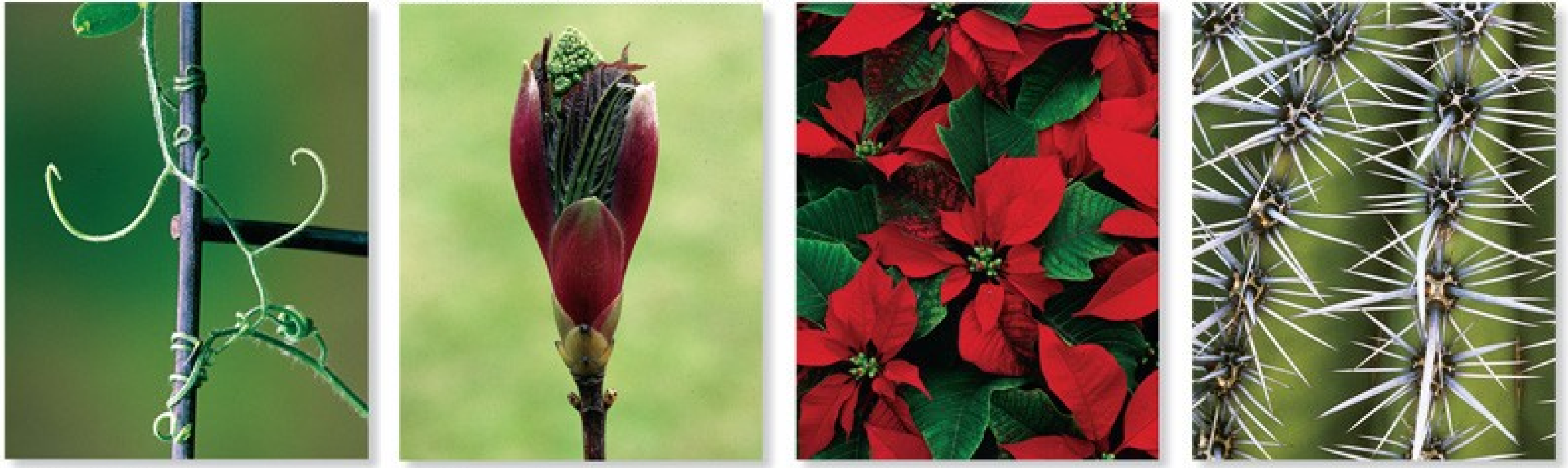
Figure 35.17a–c



(c) Leaf internal structure

© Lee W. Wilcox

- Leaf veins composed of **vascular tissue**
  - **Xylem** conducts water and minerals
    - Roots ☾ leaves
  - **Phloem** carries sugar products of photosynthesis
    - Leaves ☾ roots
    - Leaves to apical meristems



(a) American vetch (*Vicia americana*) (b) Sycamore (c) Poinsettia (d) Giant saguaro cactus

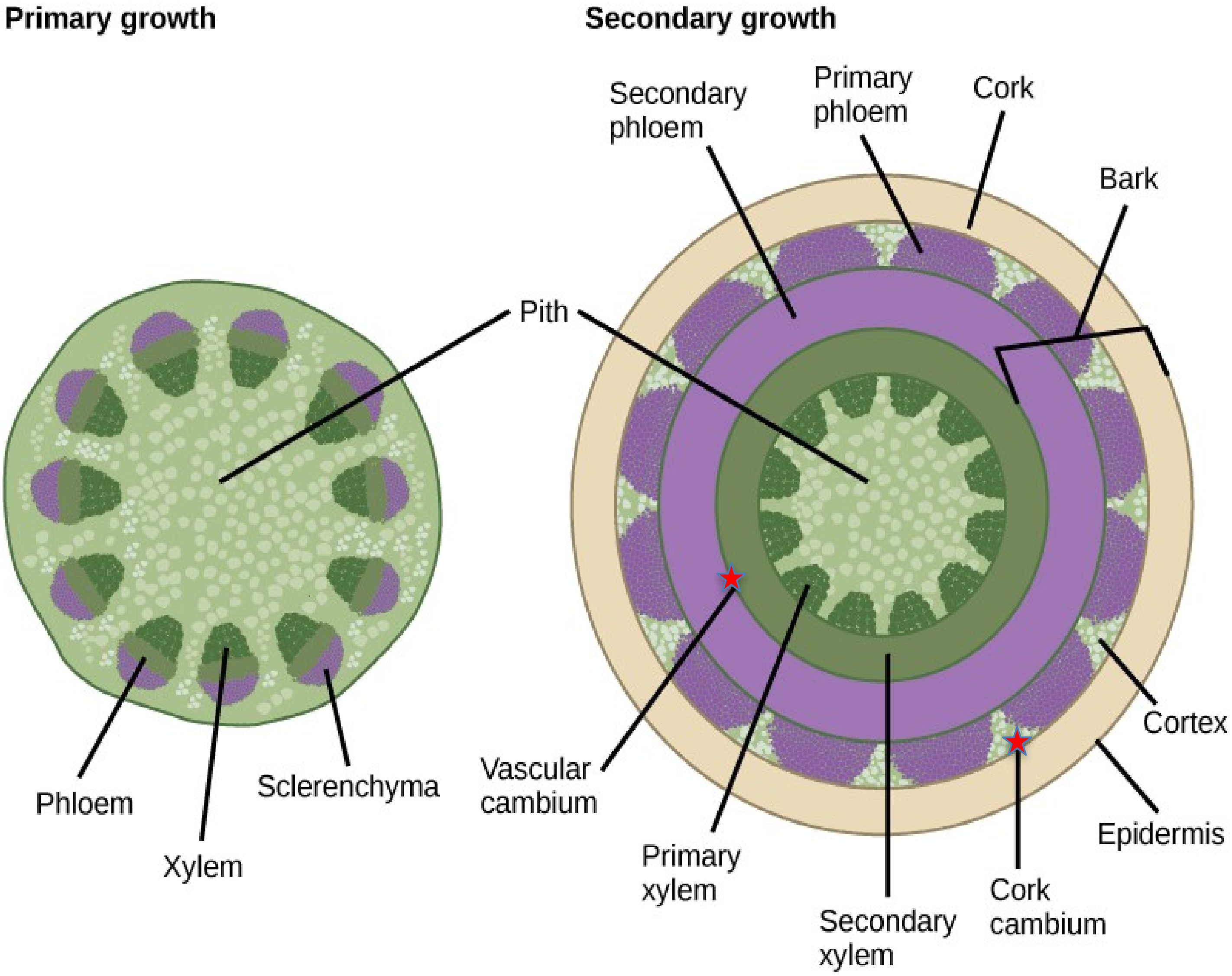
a: © Ed Reschke/Peter Arnold, Inc.; b: © John Farmar; Cordaiy Photo Library Ltd/CORBIS; c: © Steve Terrill/CORBIS; d: © John Gerlach/Earth Scenes

- Most leaves function primarily in photosynthesis
- But **leaves can be modified** for other roles
  - Tendrils
  - Tough scales that protect buds
  - Poinsetta “petals” (=bracts)
  - Cactus spines are modified leaves (but thorns = modified stems)

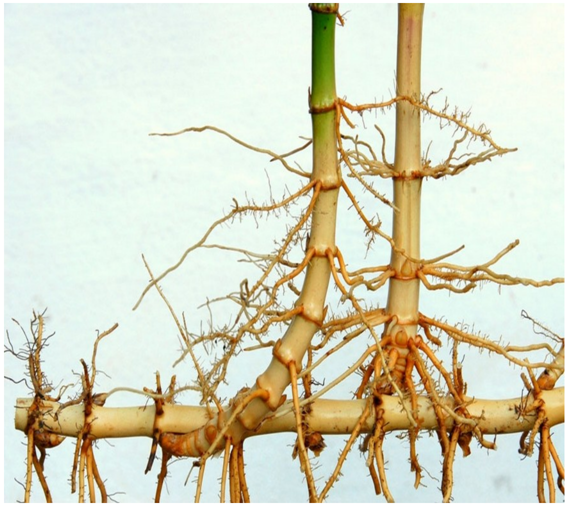
Stem vascular tissue

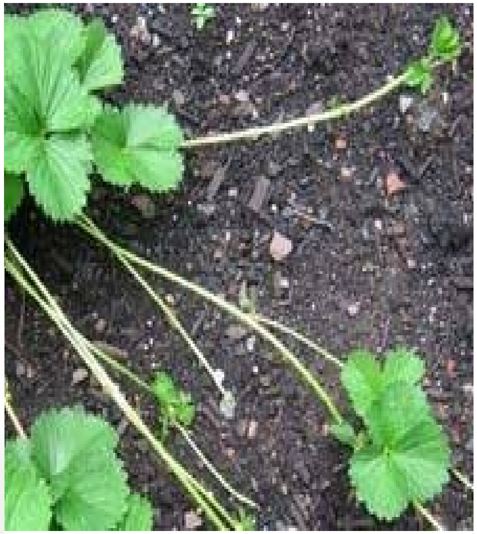
- Herbaceous plants produce mostly **primary vascular tissues**
- Woody plants produce **primary and secondary vascular tissue**
    - ❑Secondary vascular tissue formed from secondary or lateral meristems (also termed the vascular meristem or cambium) that encircle the trunk

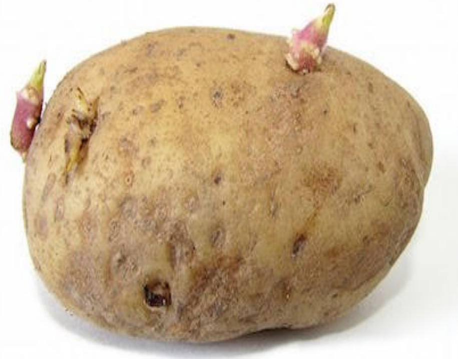
Vascular tissue



Modified stems

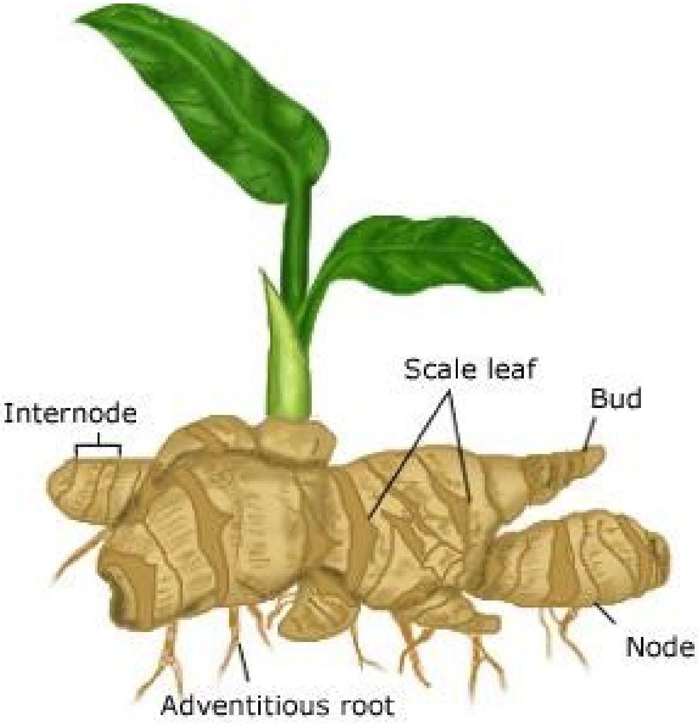


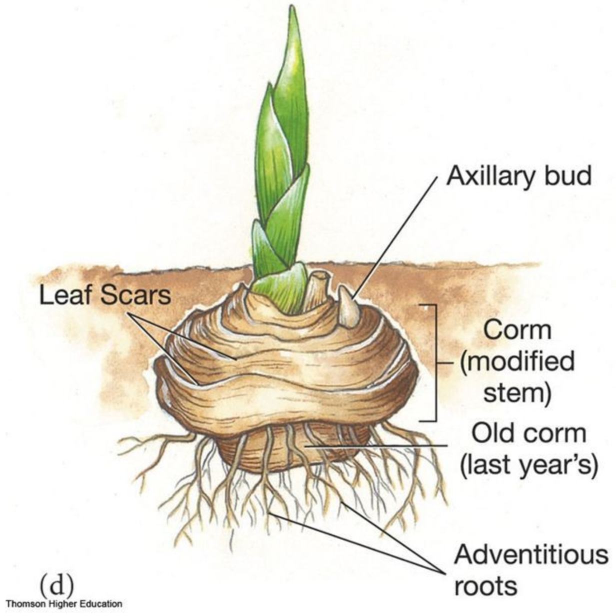


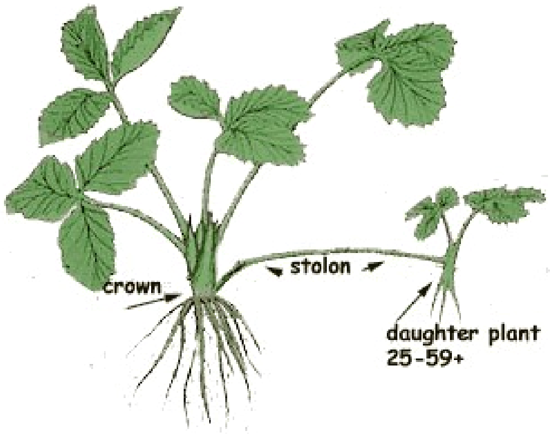


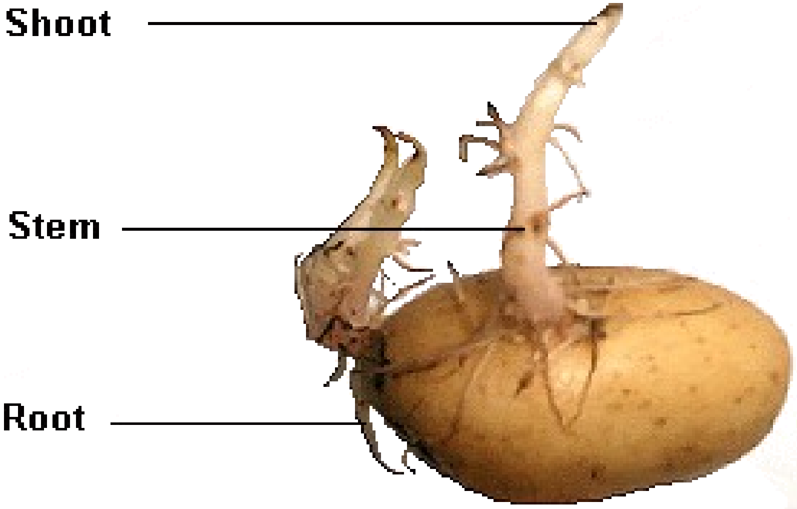
- **Rhizomes** – underground stems
- **Stolon** (= runner) – aboveground stem
- Grass stems grow as rhizomes (below ground) or stolons=runner (above ground)
- Potato **tubers** store food

Modified stems









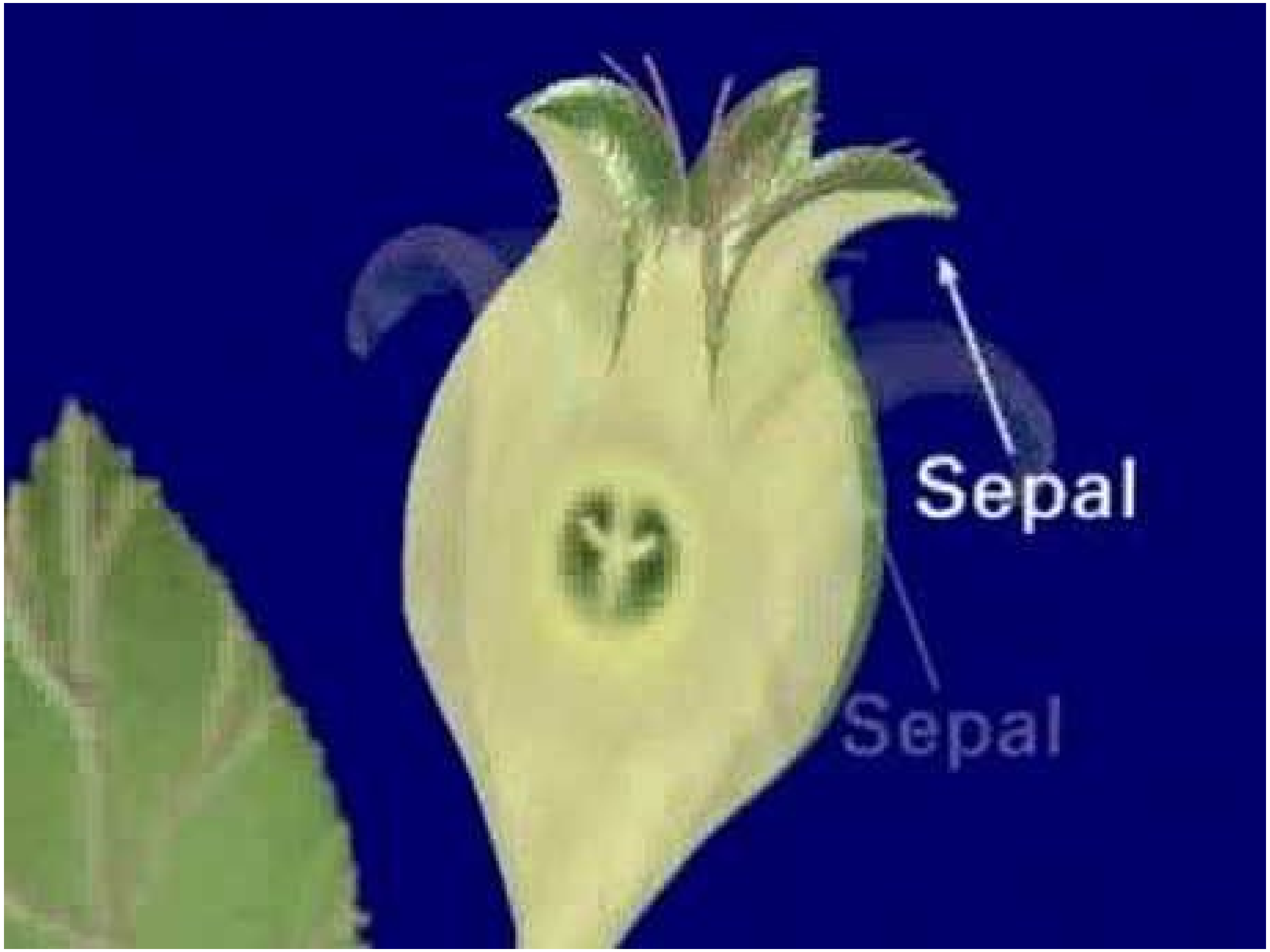
Flower Diversification

- **Simple flower**
- **Clustering of flowers** into groups are termed inflorescences.
    - e.g., Sunflowers
- **Reduction of the perianth** (sepals and petals)
    - Grass flowers are wind pollinated
- **Fused petals**
    - Floral tubes accumulate nectar for pollinators

FRUITS

- Develop from ovary walls as it matures with seeds inside (protection)
- Aid the dispersal of enclosed seeds
- Dispersal prevents competition with parent plant and aids in colonization
- Fruits may be adapted
  - To attract animals to eat them
  - For wind dispersal
  - To attach to animal fur
  - To float in water

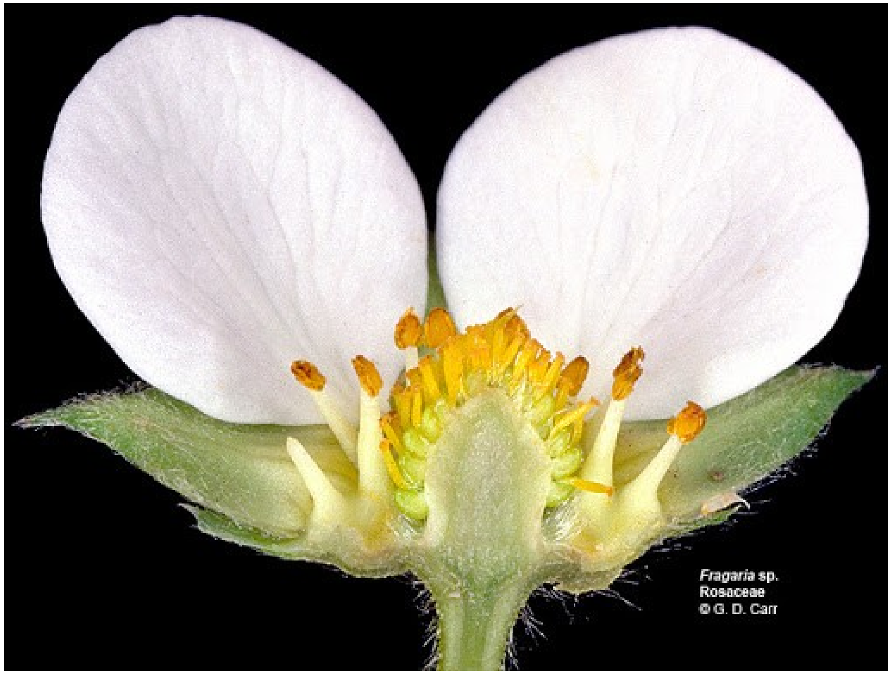
Fruit development



1 flower
(1 ovary)

Many flowers
(many separate ovaries)

1 Flower
(several separate ovaries)

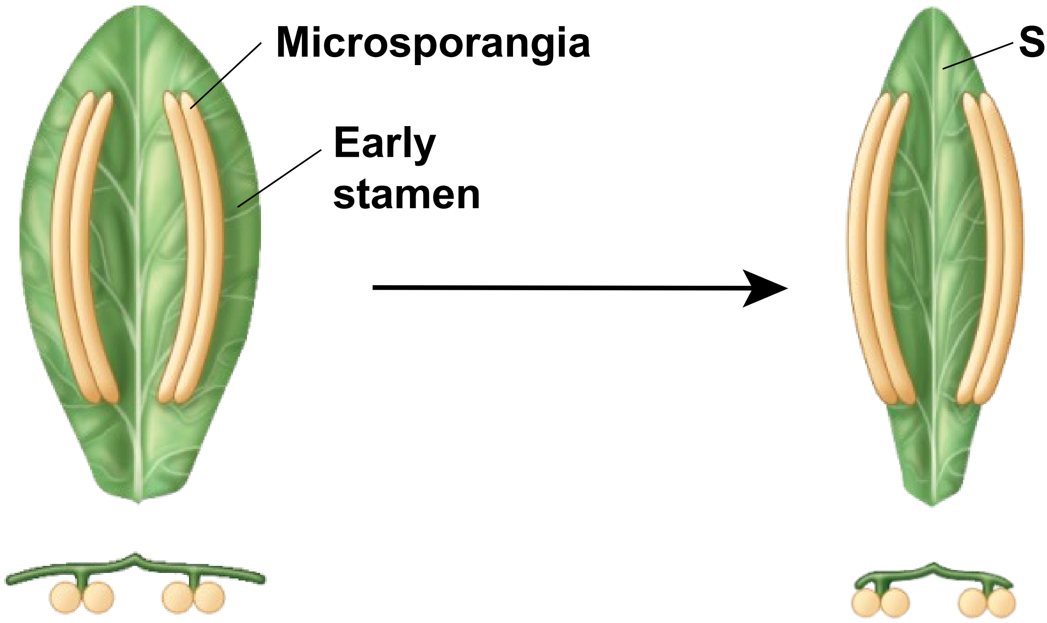


Early flowers

- First appeared 140 mya (mammals at 210mya)
- Flowers were a **critical innovation** that led to extensive angiosperm diversification
- **Stamen** development
  - Early flowers had broad leaf-shaped stamens
  - Narrowed to form filaments and anthers (clusters of microsporangia with pollen)
- **Carpels** also developed from leaf-like structures
  - Folded to protect ovules

1 **Early stamens were leaflike, with microsporangia on the surface.**

2 **Stamens later became narrower.**



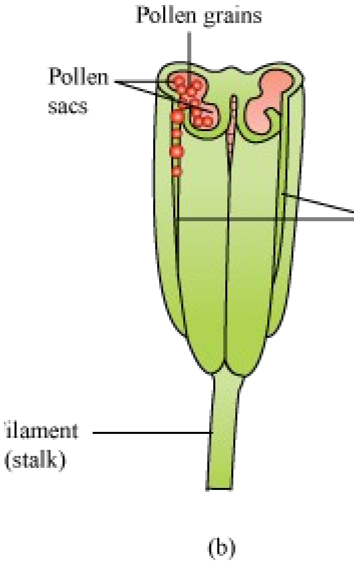
Front view

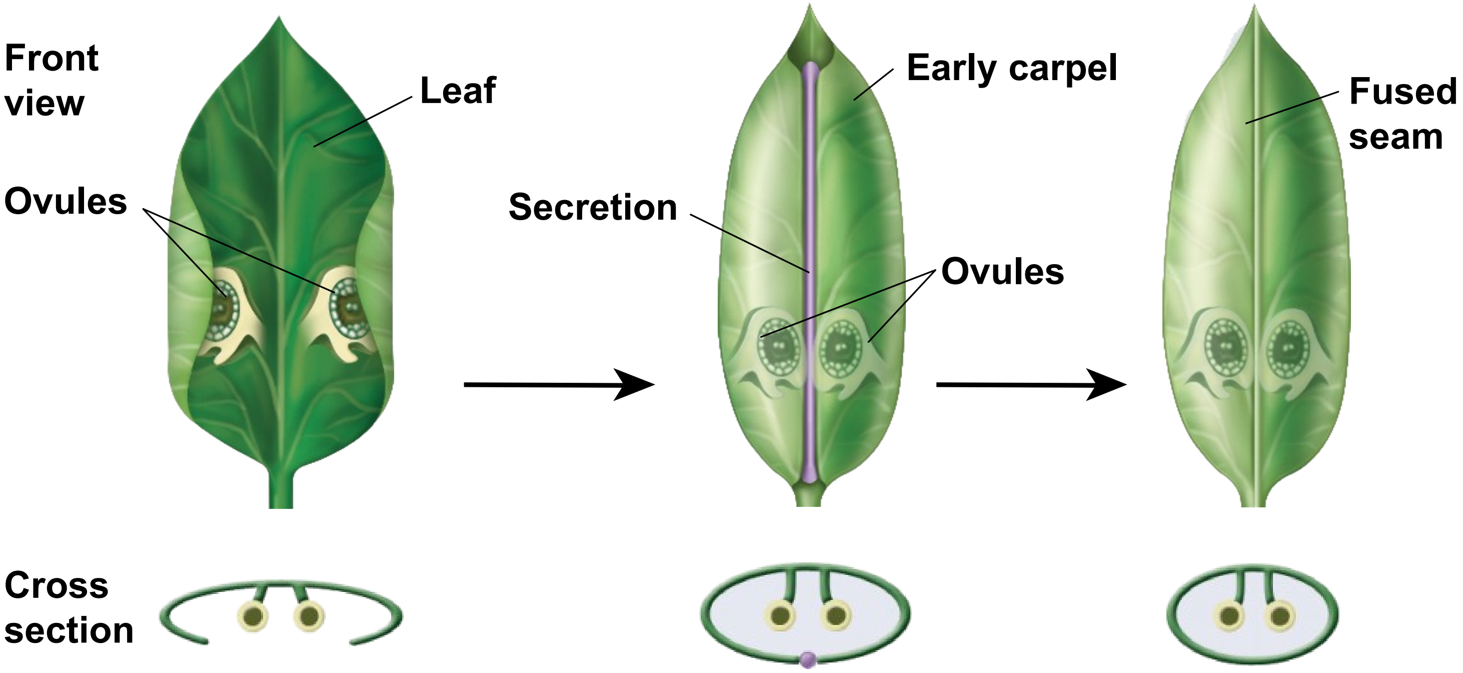
Microsporangia

Early stamen

Stamen

Cross section

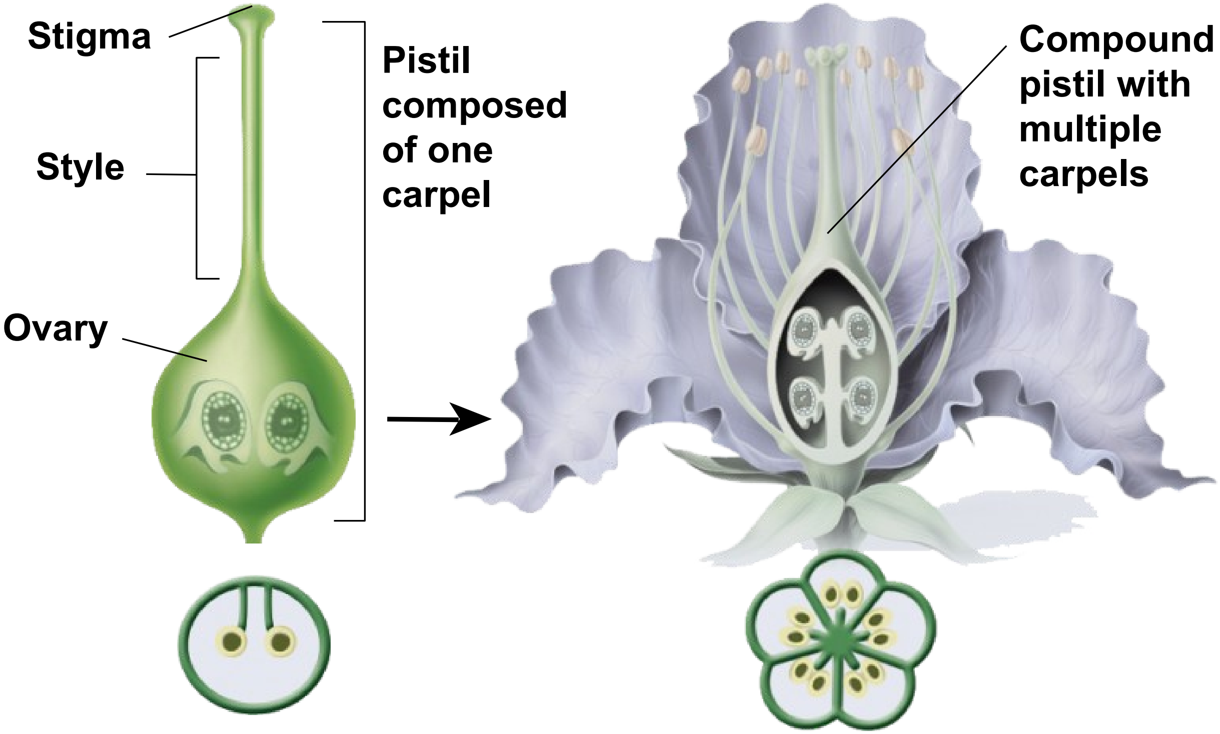




1 Carpels evolved from leaflike structures whose edges folded over ovules, protecting them.

2 Early carpels folded over ovules, with the seam closed by sticky secretions.

3 Later carpels were completely closed into a tube, by fusion of tissue.


Stigma
Style
Ovary
Pistil composed of one carpel
Compound pistil with multiple carpels

4 Carpels developed specialized regions (stigma, style, and ovary) to form a pistil.

5 In many modern flowers, several to many carpels fuse to form a compound pistil.

The Role of Coevolution in Angiosperm Diversification

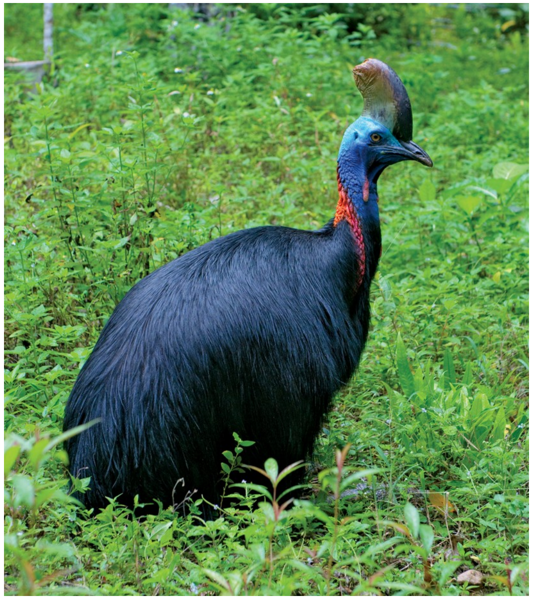
- Process by which two or more species of organisms influence each other's evolutionary pathway – they exert selective pressure on each other.

- Explains the diverse forms of most flowers and many fruits, and how plants accomplish effective pollen and seed dispersal.

Seed-dispersal coevolution

A bird eating berries containing seeds that will be dispersed later with the animal's feces

- Influenced both plant fruit charcteristics and animal seed-dispersal agent
- Plant may have juicy, sweet fruit with small seed to readily pass through gut
- Plants may signal fruit ripeness with color change
- Cassowaries in Australia disperse over 150 species of plants and can process the largest seeds.



Pollination coevolution

- Pollinators foster genetic variability and plant potential for evolutionary change
- **Constancy** or **fidelity** – pollinators learn the flower characteristics and visit them preferentially
  - Precise pollen transfer
- Attract appropriate pollinator using attractive colors, odors, shapes, sizes

Pollination syndrome

- Some flowers specialized for particular pollinators
- **Birds** – odorless red flowers
- **Bees** – blue, purple, yellow or white flowers with a sweet odor
- If pollinator becomes extinct, plant may also face extinction (**Joshua tree & Yucca moth**)

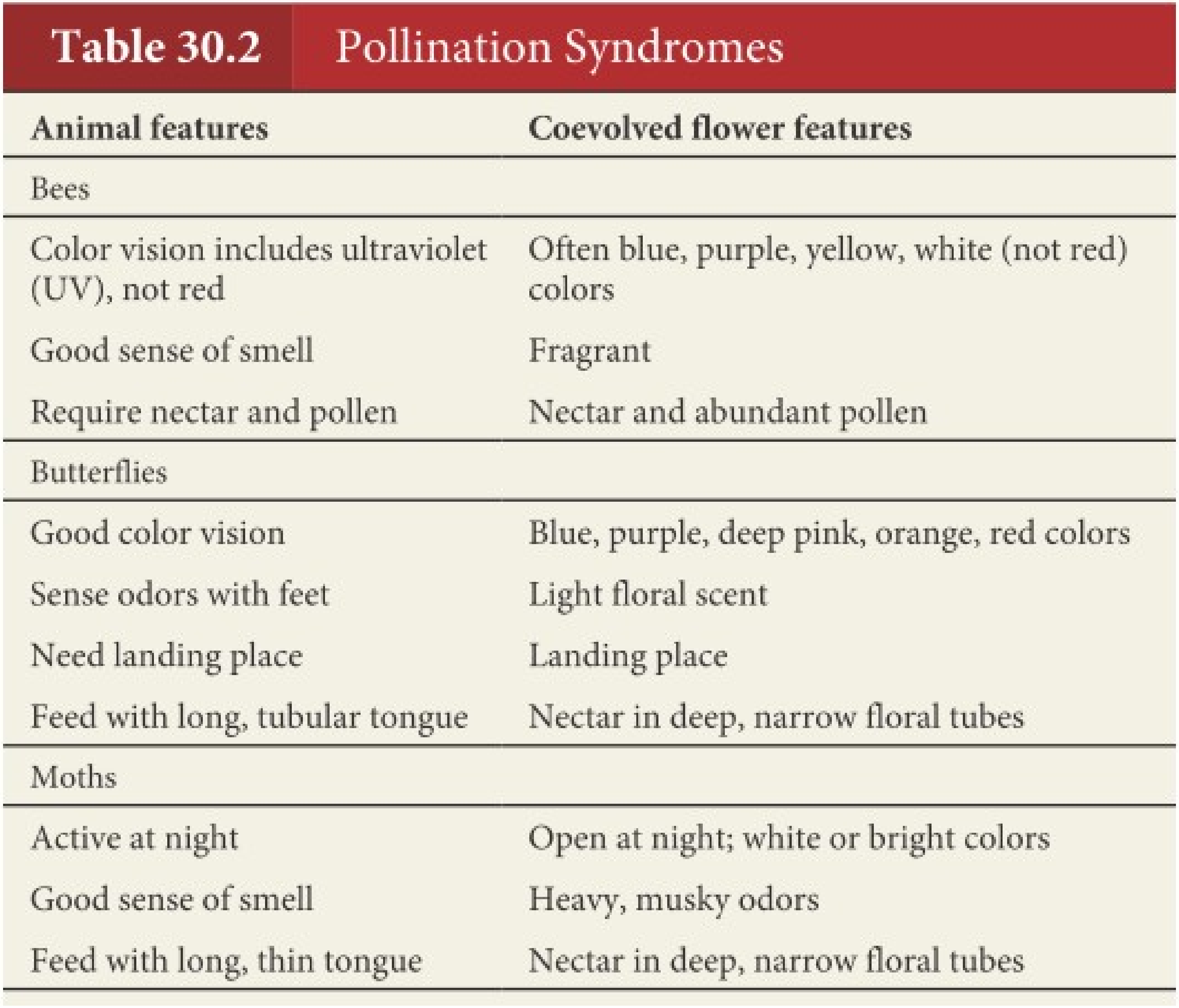


Table 30.2 Pollination Syndromes

Animal features	Coevolved flower features
Bees	
Color vision includes ultraviolet (UV), not red	Often blue, purple, yellow, white (not red) colors
Good sense of smell	Fragrant
Require nectar and pollen	Nectar and abundant pollen
Butterflies	
Good color vision	Blue, purple, deep pink, orange, red colors
Sense odors with feet	Light floral scent
Need landing place	Landing place
Feed with long, tubular tongue	Nectar in deep, narrow floral tubes
Moths	
Active at night	Open at night; white or bright colors
Good sense of smell	Heavy, musky odors
Feed with long, thin tongue	Nectar in deep, narrow floral tubes

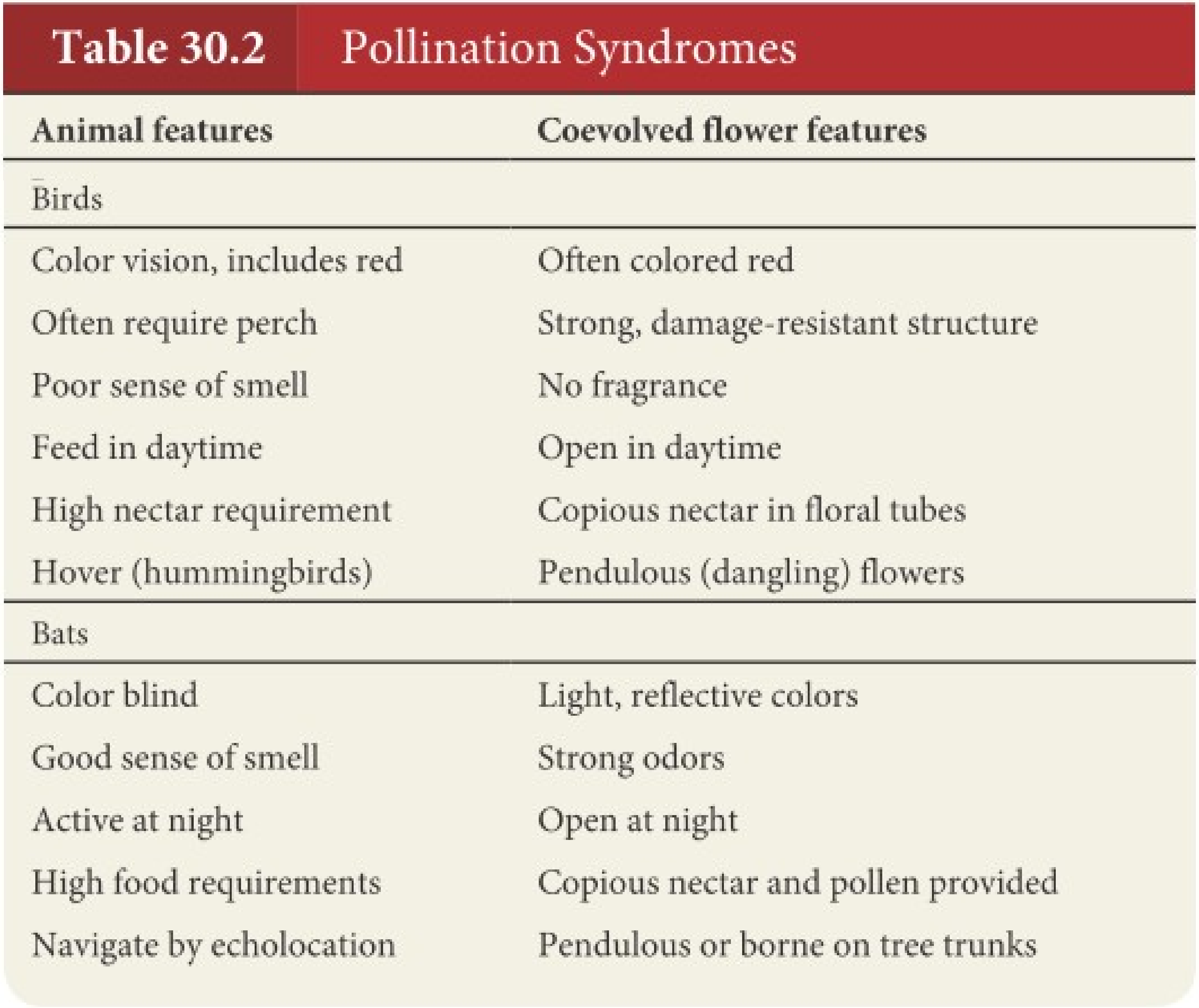


Table 30.2 Pollination Syndromes

Animal features	Coevolved flower features
Birds	
Color vision, includes red	Often colored red
Often require perch	Strong, damage-resistant structure
Poor sense of smell	No fragrance
Feed in daytime	Open in daytime
High nectar requirement	Copious nectar in floral tubes
Hover (hummingbirds)	Pendulous (dangling) flowers
Bats	
Color blind	Light, reflective colors
Good sense of smell	Strong odors
Active at night	Open at night
High food requirements	Copious nectar and pollen provided
Navigate by echolocation	Pendulous or borne on tree trunks

TED talk: Pollinators 7min (start at 3:16)

What Plants Talk About